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WASTEWATER TECHNOLOGY CENTRE

ANNUAL REPORT
FISCAL YEAR 1986/1987

TECHNOLOGY DEVELOPMENT & TECHNICAL SERVICES BRANCH

ENVIRONMENTAL PROTECTION

WASTEWATER TECHNOLOGY CENTRE

ANNUAL REPORT

Fiscal Year 1986/1987
(April 1, 1986 - March 31, 1987)

TECHNOLOGY DEVELOPMENT AND TECHNICAL SERVICES BRANCH

ENVIRONMENTAL PROTECTION

CONSERVATION AND PROTECTION

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Wastewater Technology Centre
Canada Centre for Inland Waters
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario L7R 4A6

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THE WASTEWATER TECHNOLOGY CENTRE - A PERSPECTIVE

Dr. B.E. Jank - Acting Director

The Wastewater Technology Centre (WTC) is located at the Canada Centre for Inland Waters (CCIW) in Burlington, Ontario. The WTC is a component of Conservation and Protection (C&P), Environment Canada. It operates within C&P's Technology Development and Technical Services Branch (TDTSB) of Environmental Protection (EP). The TDTSB also manages the River Road Environmental Technology Centre (RRETC), a similar facility located in Ottawa. The RRETC is primarily involved with air pollution measurement, vehicle emission testing and environmental emergencies technology development.

The role of the WTC is to initiate and implement environmental control technology development programs which address C&P's priority concerns. To fulfill this mandate, facilities consisting of a wide variety of wastewater and sludge treatment pilot plants, offices and laboratories are housed in a two-storey building (the WTC), located at the CCIW site.

Screened and degritted municipal sewage is pumped continuously to the WTC from the nearby City of Burlington Skyway Pollution Control Centre. Storage tanks located north of the WTC are provided for receiving trucked industrial wastes and sludges which may be used for specific pilot scale process development studies. Effluents from all operations are discharged to the City of Burlington sewer system.

The WTC also has a fleet of mobile treatment systems which are specially fitted with laboratory and pilot scale process equipment. This provides the flexibility needed to respond to specific industrial and/or municipal process development and demonstration study requirements anywhere in Canada.

The staff of 45 permanent and 8 term employees includes engineers, a research scientist, physical scientists, a computer systems analyst and programmer, chemists, technologists and administrative personnel. As shown in Figure 1, the staff is organized into three process sections, Biological Processes, Physical/Chemical Processes, and Residue Management, and three support services sections, the Computer Services, Engineering Support and Laboratory Services. They are all supported by administrative personnel. A staff list is presented as Appendix A.

To ensure that the WTC pilot plant facilities are fully utilized, a significant number of the projects are conducted by process consultants. A large portion of the funding for the WTC program comes from other federal government agencies, provincial governments, municipalities and industries.

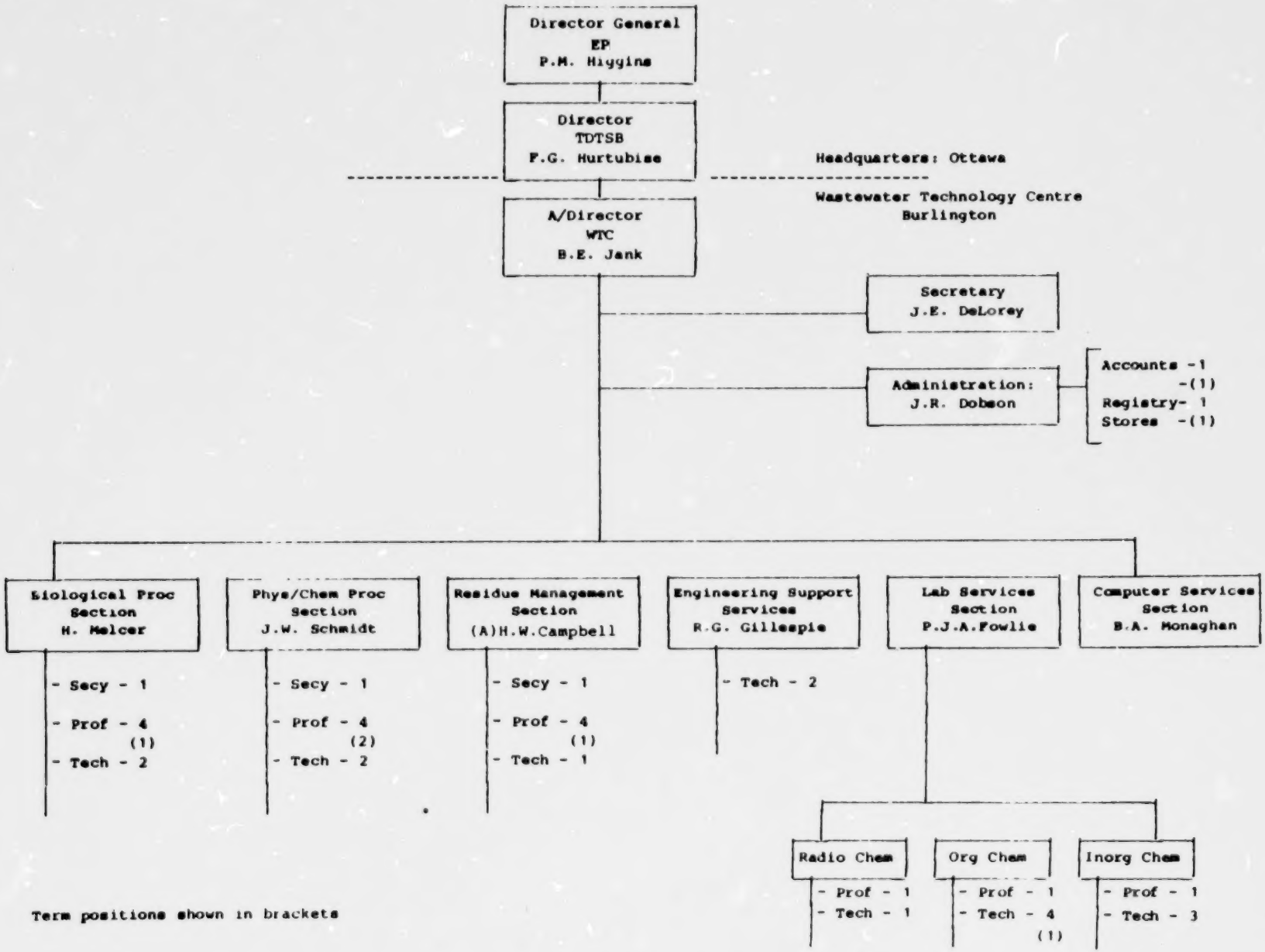

FIGURE 1. WASTEWATER TECHNOLOGY CENTRE - ORGANIZATION CHART, MARCH 1987

WTC Programs

The WTC's programs address the following C&P priority concerns: toxic chemicals, energy related activities, acid rain, northern development, St. Lawrence River, Fraser River Estuary and the Great Lakes Specific projects requested by C&P Headquarters organizational units and/or the C&P Regions to address these priority concerns would normally be included in one of the following general program areas:

- Development of analytical techniques for characterization of wastewaters, leachates, hazardous liquid wastes and residues containing toxic chemicals.

- Assessment and demonstration of the toxics reduction capability of existing treatment technologies.

- Development and demonstration of innovative treatment technologies for energy efficient pre-treatment or complete treatment of complex industrial wastes, residues, leachates or hazardous liquid wastes.

- Development of operations management strategies which maximize contaminant reduction and minimize operating costs by optimizing treatment plant operation.

- Assessment, development and demonstration of cost effective technologies for the handling, treatment and disposal of municipal and industrial residues containing toxic chemicals.

The major developmental research and demonstration program areas for the Biological Processes Section continued to be high-rate anaerobic treatment of high strength, high temperature industrial wastewaters; automated process control of activated sludge systems; and the fate of toxic trace organic chemicals in biological treatment systems. For the source control anaerobic program, a greater emphasis was placed on the demonstration of the technology in pulp and paper applications. The automated monitoring and control strategies development program aimed at improving process performance and system reliability of anaerobic reactors continued to be a high priority activity. Results from the Tillsonburg automated process control demonstration project were used to develop a process audit capable of identifying design deficiences at existing facilities. At the Kitchener WPCP it was used to show that existing tankage and upgraded aeration equipment could meet nitrification requirements beyond the year 2011; a $0.5 million system upgrade which included an automated control system deferred a $20 million plant expansion. An increased effort in programs involving the effectiveness of technologies for the removal of trace organics from wastewaters was in direct support of the Ontario Ministry of the Environment's Municipal and Industrial Strategy for Abatement (MISA) program. The MISA initiative,

involving the development of a monitoring regulation and a control regulation for municipal and industrial dischargers, requires considerable technical support as there is a limited amount of statistically significant data on the fate of trace contaminants in treatment systems.

The major emphasis for the Physical/Chemical Processes Section continued to be placed on projects involving the treatment of effluents from gold mining operations and in-situ bitumen/heavy oil recovery facilities. In the gold mining sector, programs on natural degradation and INCO's SO_2/air process will be expanded to obtain the additional information required for the MISA program. The program involving the development and demonstration of cost-effective technologies for treatment of produced water from bitumen/heavy oil operations included extensive characterization and bench scale treatability studies, plus pilot scale filtration studies for oil and suspended solids removal at Husky Oil's Aberfeldy operation near Lloydminister, Alberta. Negotiation with Alberta Oil Sands Technology Research Authority (AOSTRA), and five oil companies continued throughout the year in preparation for the 1987 field study on total dissolved solids removal from produced water in the Lindberg area of Alberta. An extensive research program involving development of process control and monitoring strategies for granular media filters has been extremely useful in the optimization of the design and operation of the produced water filtration studies. Although some bench and pilot scale studies were conducted on groundwater contaminated by landfill leachates funding could not be obtained for a major demonstration project involving this high priority research topic.

The major areas of Residue Management Section research conducted during 1986/87 continued to be the demonstration of liquid fuel production from sewage sludge; development of control strategies for sludge dewatering; assessment of solidification as a hazardous waste management control option; and assessment of fate and degradation of toxic organics in sludge applied to land. The one tonne per day pilot scale reactor for the conversion of sewage sludge to synthetic oil was installed at the Hamilton WPCP in September by Petro Sun International Inc. Preliminary runs confirmed that the pilot plant operated as expected. The US patent "Process and Apparatus for the Conversion of Sludges" was issued in October. Zenon Environmental Inc. under their PILP contract, developed a prototype sludge conditioning controller (SCC) which was tested on the 0.5 m belt press at WTC. Following the negotiation of a license between Zenon and Canadian Patents and Development Ltd., a field model Zenon SCC was installed at the Guelph WPCP on a 3 m Komline-Sanderson belt press. Although existing sludge handling equipment required upgrading, preliminary evaluation data indicated that the SCC performed as anticipated. Results from the WTC, Alberta Environmental Centre, US EPA and the US Army Corps of Engineers Waterways Experiment Station Cooperative Solidification Study were analyzed and interpreted in preparation for the May 1987 International Symposium on Solidification. Additional studies involving the immobilization of trace organics in hazardous wastes and heavy oil sludges have provided an opportunity to further assess the applicability of existing processes. Experimental studies on land application of oily sludges continued at WTC. The program was expanded by incorporating an

evaluation of US EPA's Ritz model into an industrial decommissioning study being performed by Monenco at Texaco's Nanticoke refinery. Another component of the program involves a bench scale study to determine whether biological degradation can be appropriately managed to decontaminate soil containing chlorinated organic compounds. The initial development program involves enhanced PCB degradation in contaminated soil received from Federal Pioneer in Regina.

Technology Transfer

Technology transfer is the bridge between research and development and full scale application of new technology. To ensure the most effective use of limited research and development resources, it is important that, as soon as new, cost effective wastewater treatment technology is developed and demonstrated, it is incorporated into the design, construction and operation of waste treatment facilities.

To help accomplish this, TDTSB has a technology transfer seminar program focusing attention on new developments in the water pollution control field. The WTC contributes substantially to this program each year. Comprehensive reports dealing with research and development projects are published in the Research and Technology Development category of the EP report series which are available upon request from Ottawa. Staff continue to not only present papers at technical and scientific conferences, workshops, seminars and symposia but also assist with their planning and organization. The publication of these papers in referred journals, symposia proceedings and other trade journals represents one of the most effective mechanisms of technology transfer. An index to reports, papers and presentations by WTC staff is found in Appendix B.

Quarterly reports presenting the objectives, work statement and an updated project status report for each project are prepared by the process sections. In FY 1985/1986, a WTC newsletter was introduced to provide information on current research projects and other topics of general interest to clients and colleagues. The WTC has a brochure suitable for distribution to the general public, describing the nature of the research conducted at the WTC. Copies of the quarterly reports, newletter and brochure are available upon request from the Director.
A 16 mm colour film in either French or English, entitled "Wastewater Technology Centre", showing the activities of the WTC staff, is available at no charge for educational screenings or television broadcasts.

WTC personnel are also assisting in the dissemination of Canadian water pollution research information by accepting responsibility for distribution of the Water Pollution Research Journal of Canada. This refereed journal is published quarterly by CAWPRC, the Canadian Association of Water Pollution Research and Control.

Each year many visitors, local, national and international, tour the WTC facilities and meet with staff for technical information exchanges.

PROJECT STATUS REPORTS - BIOLOGICAL PROCESSES SECTION

SECTION: BIOLOGICAL PROCESSES

PROJECT MGR: H. Melcer

PROJECT NO. 99702

TEL: 336-4546

ACTIVITY NO: 2300

TITLE: BIOLOGICAL FLUIDIZED BED TREATMENT OF COMPLEX ENERGY PRODUCING INDUSTRY WASTEWATERS

OBJECTIVE

To determine the feasibility of removing toxic chemicals and nitrogen-containing contaminants in aqueous wastes from tar sands upgrading, heavy oil upgrading and coal liquefaction processes using predenitrification nitrification (PDN) process technology.

RELEVANCE

The removal of toxic chemicals and nitrogen-containing contaminants from industrial wastewaters is being demonstrated in support of the Industrial Programs Branch requirement to develop codes of practice for the oil and gas, synfuels and steel industry sectors.

WORK PLAN

1. **Taciuk Process.** The bench-scale aerobic and anaerobic treatability studies initiated in 1985 will be completed and a report submitted by August. If the condensates are treated successfully and the UMATAC process demonstration project proceeds, fluidized bed investigations will be undertaken at the WTC.

2. **Canmet Hydrocracker.** Sampling of the discharge from the Canmet demonstration upgrader, located at the Petrocan refinery in Montreal, will be initiated in the spring of 1986. Following wastewater characterization, bench-scale treatability studies will be initiated.

3. **Heavy Oil Upgraders.** Subject to Federal government - industrial financial accords, preliminary wastewater characterization and treatability investigations will be undertaken during 1986.

4. **Coal Liquefaction.** Unsteady-state experiments on the coupled fluidized bed system, initiated in 1985, will be completed. Two reports will be prepared that address all phases of work carried out since 1981. The first to be submitted by July 1986 on the steady-state experiments.

PROJECT NO. 99702
Page 2

STATUS REPORT - APRIL 1986 to MARCH 1987

1. Taciuk Process. The powdered activated carbon activated sludge treatment assessment of UMATAC condensates was completed in May. This concluded the experimental program initiated last Fall. A report was prepared and reviewed by UMATAC in December. The report was modified and distributed in March. All subsequent Taciuk process development activities were suspended in 1986.

2. Canmet Hydrocracker. The hydrocracker startup took longer than anticipated. No samples of discharge wastewaters were available during the year. Samples of liquid and solid wastes from the Canmet coal coprocessing pilot reactor at Bells Corners were analyzed in a preliminary assessment of the environmental impact of the coal coprocessing technology.

3. Heavy Oil Upgraders. The decline in the world price of oil suspended any further project development in Canada.

4. Coal Liquefaction. A second dynamic experiment was carried out in June which concluded the 5-year project on the treatment of coal liquefaction process condensates for the Department of Energy, Mines & Resources. A final report on the steady state portion of the work was completed in December. Delays in analysis of organic species postponed completion of the dynamic program until March.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: H. Melcer

PROJECT NO. 99703 TEL: 336-4546

ACTIVITY NO: 2400

TITLE: FATE OF TRACE CONTAMINANTS IN BIOLOGICAL TREATMENT SYSTEMS

OBJECTIVE

To determine the effectiveness of biological process technologies in removing trace contaminants from wastewaters.

RELEVANCE

Increased pressure for toxic chemicals control has generated considerable information on the control of specific contaminants such as the U.S. EPA priority pollutants, chlorinated compounds and complex nitrogenous materials. Increasing evidence in the literature and from in-house work shows that biological systems are capable of achieving high levels of contaminant control.

This work responds to the requirements of the Technology Development and Technical Services Branch toxic chemical control activities and supports the Industrial Programs Branch needs in developing codes of practice for the control of trace contaminants in the municipal and industrial sectors.

WORK PLAN

1. **Toxic Chemicals Laboratory.** The construction of a laboratory that meets the health and safety codes required when working with toxic chemicals will be completed in 1986. This will have the capacity for operating six bench scale activated sludge systems simultaneously. It is hoped to initiate, later in 1986, work to demonstrate the effect of SRT control on the removal of specific organic contaminants.

2. **Variability of Specific Contaminants.** Multiple sampling of the influents and effluents of three municipal wastewater treatment plants will be undertaken to evaluate their capacity in dealing with dynamic fluctuations in trace organic contaminants.

3. **MISA.** Technical support will be provided to the Ontario Ministry of the Environment in the development of their MISA program.

STATUS REPORT - APRIL 1986 to MARCH 1987

1. **Toxic Chemicals Laboratory.** The installation of flow-through cabinets and ancillary services was completed in August. Cost estimates for the mechanical air ventilation equipment were considerably above budget which prevented the completion of the Toxics Laboratory this fiscal year.

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2. Contaminant Variability Study. A literature search was prepared by the contractor. Samples were collected at 2 hr intervals over an 8 day period at the Waterloo STP in July, at Welland STP in August and at Galt STP in October. The portion of work in which the influence of recycle streams on effluent trace contaminant variability was cancelled. This resulted from the observation that minimal variability occurred in the effluents of the three STPs despite considerable influent trace contaminant loading. The funds for the recycle stream work were reallocated to an expanded Phase 3 work program in which the fate of contaminants are being assessed in laboratory scale activated sludge reactors. The three systems were started up in January and toxicity tests were completed by March.

3. MISA. Technical support was provided to the Municipal, Petroleum and Chemical Sectors of Working Groups 2 and 3 in the development of the monitoring regulation for these three sectors.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: D.T. Chapman

PROJECT NO. 99706 TEL: 336-4621

ACTIVITY NO: 2400

TITLE: STATISTICAL EVALUATION OF PERFORMANCE DATA

OBJECTIVE

To evaluate and develop cost-effective sampling programs for ensuring the validity of data collected to characterize the performance of wastewater treatment processes with respect to both conventional and trace pollutants.

RELEVANCE

The performance of a wastewater treatment plant is characterized by collecting and analyzing effluent samples. Such data establish whether a plant is in compliance with effluent standards or guidelines. In addition, mass discharge rates from wastewater treatment plants are often used as inputs in mass balances of a pollutant for a lake or river. If too few samples are taken or if inadequate techniques are used to collect the samples then the results of the survey will be confusing or meaningless. Obtaining more samples than necessary is expensive and time consuming. The trade offs are particularly difficult for programs involving the analysis of toxic trace organics as the cost of an individual analysis is high and the results often highly variable. Therefore, information is required so that efficient and cost-effective sampling programs can be produced for wastewater treatment plants.

WORK PLAN

1) A written summary and annotated bibliography will be prepared concerning the techniques and sources pertaining to sampling strategies for wastewater treatment processes. (Completion date - December 1986.)

2) The statistical manual being prepared by El-Shaarawi, Demayo, and Esterby of NWRI will be reviewed and comments provided. (Completion date - October 1986.)

3) A program will be developed for identifying the sources of constituent variability arising from the process, the sampling procedures, and the chemical analysis for estimates of phosphorus discharged by municipal treatment plants practicing chemical addition. Estimates will be made of the uncertainty associated with current estimates of mass phosphorus discharge rates and recommendations made for reducing the error in such estimates. (Completion date - March 1987.)

4) Methods for analysing toxic trace contaminant data will be assessed and modified to address censored data. (Completion date - March 1987.)

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STATUS REPORT - APRIL 1986 TO MARCH 1987

1), 2) and 3) With assistance provided by Dr. El-Shaarawi, National Water Research Institute, and the Ontario Ministry of the Environment, work was initiated on the effect of sampling frequency and calculation techniques on estimates of mean phosphorus concentrations and loadings. Preliminary data analysis was conducted of daily data from 1985 from three large municipal activated sludge plants. Time series and probability plots were constructed for flow and total effluent phosphorus. "Box-and-whisker" plots were constructed of phosphorus loading (the product of the flow and total phosphorus concentration). In general, the data were found to be log normally distributed.

The sum of daily phosphorus loadings for a year was compared to yearly phosphorus loading calculated as the product of average yearly concentration and the sum of daily flows. The latter method, because of some correlation between flow and daily phosphorus concentration, tends to underestimate yearly phosphorus loading. In addition, sampling frequencies for the municipal treatment plants were examined according to plant size. A number of plants were identified as sampling at a lower frequency in comparison with other plants in their size category.

A Fortran program was written to simulate simple random, stratified random and systematic sampling strategies for the three plants. The program breaks the 1985 concentration data in months and selects data according to the sampling strategy for each month. The procedure was repeated hundreds of times for each sampling strategy and frequency. Results were combined to examine the effect of sampling frequency and sampling strategy on the 95% confidence interval for monthly mean phosphorus concentrations. The findings indicate that systematic sampling allows greater precision than simple random sampling. No significant biases were detected for the three different sampling strategies. A report on the research is in preparation. Other reports identified in 1) and 2) are in preparation.

4) Software was written for the HP-1000 to estimate the mean, standard deviation, median, and interquartile range for censored data (data with values reported as "less than detection limit"). The software was based on techniques developed by Helsel and Gilliom (Water Resources Research, Vol.22, 1986). The program was tested on synthetic data with an ideal log normal distribution and trace organic data from a study of contaminated groundwater. An overview of the approach and documentation for the software was written.

Work was conducted to obtain, examine, and demonstrate techniques for evaluating effluent data from wastewater treatment plants. Initially, a review was conducted of graphical techniques for presenting and interpreting data. A seminar on the techniques was presented to WTC staff and a set of notes with a bibliography was distributed. Software was developed for constructing "box-and-whisker" plots.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: D.T. Chapman

PROJECT NO. 99711 TEL: 336-4621

ACTIVITY NO: 2400

TITLE: UPGRADING MUNICIPAL SLUDGE DIGESTERS

OBJECTIVE

1) To optimize full scale anaerobic sludge digester mixing conditions.

2) To examine the potential for increasing volumetric organic loading rates and volatile solids reductions.

RELEVANCE

Tracer studies conducted on primary digesters by MOE and WTC have shown that mixing was inadequate; in many cases, dead space accounted for more than 75 per cent of the primary digester volume. Short-circuiting of undigested sludge was also observed. These conditions imply that digestion is capable of proceeding at a much higher rate than historically anticipated, and that anaerobic digesters are drastically over-designed with respect to volume, but under-designed with respect to mixing requirements. Substantial capital cost savings would be incurred if organic loading rates on a volumetric basis can be increased by a factor of 3 or 4 with improved mixing.

WORK PLAN

1) A final tracer run will be carried out in the third quarter at the Brantford treatment plant using the 1/3 (compressor/gas gun) configuration to establish the analytical and sampling variability.

2) A report will be prepared by December 1986 which will include a literature review of mixing in anaerobic digesters, the Brantford tracer results, and the results of a tracer study carried out on pilot-scale equipment at the WTC.

STATUS REPORT - APRIL 1986 TO MARCH 1987

During the past year, analysis was completed of data collected from a primary high-rate anaerobic digester at Brantford, Ontario. The objective of the research was to evaluate the influence of mixing power and the frequency of raw sludge pumping on the degree of mixing. The digester treated cosettled primary and waste activated sludge and was equipped with a total of 11 gas guns and three 5.6 kW (7.5 HP) compressors. Power inputs varied from 4 to 17 kW/1000 m^3 with pumping frequencies changing from 4 to 12 times per day. Using lithium chloride tracer, six residence time distribution (RTD) curves were obtained.

The RTD curves were analyzed to estimate tracer recoveries, short-circuiting, and active volumes--that portion of the total volume considered to be completely mixed. Mixing performance (as estimated by flow short-circuiting and active volume fractions) improved following the installation of automated equipment which increased the frequency at which raw sludge was pumped into the digester. The greatest improvement in mixing performance due to increased pumping frequency resulted at the lowest mixing power input. Mixing performance also improved following increases in total mixing power. The greatest improvement in active flow resulted when power input was increased at the low sludge pumping frequency.

The results from the study suggest that current power input criteria for digesters are inadequate. The contents of the digester were incompletely mixed at power inputs input which exceeded US EPA recommendations (5.3-7.9 kW/1000 m^3). In addition, the literature indicates that unit power inputs for digesters are low in comparison to other biological wastewater treatment processes. A paper summarizing the results from study, "Anaerobic Sludge Digester Tracer Studies to Assess Alternative Mixer Configurations", was presented at the 59th Annual Conference of the Water Pollution Control Federation.

In addition to the full-scale studies, research was conducted on a pilot-scale reactor. The ability of mixing models to quantify the degree of mixing was evaluated by obtaining and analyzing RTD curves from pilot-scale equipment configured to control mixing performance. The amount of dead space was controlled by changing the height of a baffle within the reactor. Holes in the baffles fitted with rubber stoppers allowed the amount of fluid exchange between the actively mixed and dead zones to be varied. Diffusers mixed the reactor zone above the baffle. The proportion of flow bypassing the main reactors was adjusted using a valve on a line which connected the reactor's inlet to its outlet. Tap water was continually metered into the reactor.

Eighteen RTD curves were obtained for various reactor configurations using Rhodamine WT tracer. Analysis of the curves revealed that tracer recoveries were consistently high. The mean percent tracer recovery was 92.2% for the 18 runs. Using regression techniques, estimates were obtained for dead space and bypass fractions. Biases were calculated by subtracting the estimated parameter values obtained from regression analysis of the RTD curves from the known values established by the reactor configuration. No significant correlation was found between tracer recoveries and biases for either dead space or bypass estimates. Bias for the dead space estimates increased when holes were opened in the baffle and fluid exchange between the zones above and below the baffle. The simple mixing models, therefore, were able to adequately quantify mixing efficiency provided that no fluid exchange occurred between active and dead zones.

A report--"Evaluation of Tracer Techniques for Assessing Mixing in Anaerobic Digesters"--is being reviewed and finalized.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: G. Speirs

PROJECT NO. 99714 TEL: 336-4745

ACTIVITY NO: 2300

TITLE: ENERGY SAVINGS IN AUTOMATED FULL-SCALE ACTIVATED SLUDGE SYSTEMS

OBJECTIVE

1) To demonstrate energy savings in full scale activated sludge wastewater treatment plants by the use of instrumentation and automatic blower control to pace air addition to respiratory demand.

2) To demonstrate effective plant solids inventory control through on-line instrumentation and control.

3) To demonstrate that the control methods improve process performance as a function of energy consumption.

4) To demonstrate more effective aeration system designs for capital and operating cost savings.

5) To demonstrate advanced distributed control of pump stations to minimize plant hydraulic disturbances and make optimum and efficient use of pumping hardware.

RELEVANCE

Energy savings have been demonstrated on a WTC pilot plant using on-line dissolved oxygen sensors and a digital controller to govern aeration requirements. The original intent of the pilot scale work was to provide the background information and justification for the application at full scale of automated operational strategies to demonstrate energy savings and improved operation. At pilot scale, no blower control nor efficient electrical power usage was necessary since building supply air was used for aeration. It is known that to convert the delivered power savings (i.e. savings in air consumption or fluid or shaft power) to realized electrical power savings (brake horsepower), blower and electrical power consumption control (e.g. power factor correction, optimum operating pressures, etc.) needs to be evaluated and optimized. The wastewater treatment user community lacks this kind of information. Moreover, the pilot scale work indicated that a chicken and egg situation existed in sizing, designing, and specifying energy efficient aeration control hardware. This situation arises because of earlier findings that peak plant organic loads (mass BOD/unit time) are not precisely equivalent to the oxygen transfer requirements on an instantaneous basis. Contrary to widely-held belief, microorganisms do not necessarily oxidize substrate at the same rate at which it is removed within the process. Until on-line monitoring and control instrumentation became available, it was not possible to recognize this phenomenon. The pilot scale data suggested that many aeration designs based on loading would result in significant overdesign.

The pilot scale work was carried out under highly controllable ambient

environmental conditions (indoors at the WTC), easily controlled hydraulic loadings, direct sludge wasting back to the sewer, no anaerobic digester supernatant return, and highly skilled operating staff. These factors do not constrain the application of the principles to the full scale, rather the skepticism of the outside user community needs to be overcome by a well executed demonstration project. This will address concerns about an area which is new to the majority of the potential users of the results (i.e. governments, consultants, industry).

WORK PLAN

The Tillsonburg WPCP (6000 m^3/d average hydraulic flow rate) has been selected for the demonstration project. A plant audit was completed in 1983 to assess the plant's suitability in terms of operational flexibility and potential energy savings, and to permit correct sizing of the hardware and instrumentation required for the plant refit. On the basis of the audit, the plant was refitted in 1984 to provide segregated aeration/clarification process trains for parallel assessment of manual versus automated operation. Commissioning of installed hardware and instrumentation was undertaken, data acquisition and control algorithms were implemented and preliminary data were assessed. In 1985, the commissioning of installed instrumentation, final control elements and control loops for the main plant and upstream pump station continued. Experience with the control system/treatment plant interaction was gained as preliminary data were gathered. Results of initial energy consumption monitoring confirmed the expected aeration energy saving of 30-40%.

A structured experimental program will be initiated to evaluate aeration energy consumption and plant performance with and without control. Results will be documented and evaluated. As part of a cooperative agreement with the US Environmental Protection Agency, the maintenance requirements and reliability of on-line instrumentation and control hardware will be evaluated and reported. Based on the results of the experimental plan, options for optimizing the treatment train/control system to handle the entire plant throughput will be examined.

STATUS REPORT - APRIL 1986 TO MARCH 1987

The automated aeration control strategy was modified to incorporate a model-based predictor of air delivery and distribution, pressure, and power consumption. This approach more effectively used the capability of the computer to reduce the complexity of the control algorithm and improve the performance of the controller. As a result, the variance in the dissolved oxygen (DO) measurement around the setpoint was reduced and the air delivery system was more efficiently configured which led to an overall reduction in blower operating pressure and minimized energy consumption.

Extensive performance testing of the aeration systems was completed using two techniques for evaluating the overall oxygen mass transfer coefficient ($\alpha K_L a$) under process conditions. A technique using off-gas monitoring equipment was compared with traditional air flow manipulation and DO

response analysis techniques. The off-gas technique gave very good reproducability and was influenced to a lesser degree by changes in respiration rate. However, this method cannot be carried out automatically, and requires rigorous equipment setup and considerable operator experience. The more traditional airflow manipulation technique gave comparable results when carried out during periods of steady respiration rate. This technique can also be scheduled to run automatically at times when the respiration rate is changing slowly and accurate results can be assured. The off-gas technique continues to be carried out periodically as a standard reference.

A structured experimental program was initiated to determine the energy savings at differing DO control setpoints as compared to manual operation. While this program was considerably delayed and subsequently interrupted because of overall plant loading upsets, sludge hauling and land disposal disruptions, and scheduled major maintenance requirements, a number of experimental runs were completed. Under nitrifying conditions at 6 days solids retention time (SRT), data from the automated train showed that if the maximum airflow demand observed under automated control had been supplied throughout the same 24 hour period by operating the blowers at fixed output (typical in manually controlled plants), the expected savings in aeration resulting from automated control was in the order of 25 to 30 percent. However, the direct side-to-side comparison of operation under manual versus automated aeration control showed that the actual aeration savings achieved was only 5 to 15 percent. Further investigation and data analysis is continuing to determine why the potential energy savings were not realized in a direct side-to-side comparison.

Additional experimental runs were completed in December under parallel manual versus automatically controlled operation at 3 days SRT. The plant was operated at minimum DO levels (oxygen deficit for part of each day) in an attempt to eliminate nitrification and provide operating conditions which were considerably different from those during the previous experimental runs. The nitrification could not be eliminated and therefore the runs were completed under full nitrification at various DO setpoints. The results showed aeration savings in favor of the automated treatment train in the order of 20 percent.

The plant was configured to put the entire plant flow through the automated process train in January. This short term operating configuration was used to establish whether, through automated control the effective capacity of the plant can be increased or better utilized while maintaining plant reliability. It was found that the automated train could handle the entire plant throughput under nitrifying (6d SRT) conditions. The degree to which clarification capacity could be reduced was not fully delineated because of sludge disposal interruption. However, the results did confirm that the existing plant capacity could be optimally utilized using automated control to effectively postpone expansion.

The ongoing evaluation of instrumentation maintenance requirements continued. Means for on-line checking of instrument integrity continued to be investigated and evaluated.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: G. Speirs

PROJECT NO. 99715 TEL: 336-4745

ACTIVITY NO. 2400

TITLE: TECHNICAL SUPPORT FOR USERS OF ACTIVATED SLUDGE AUTOMATED CONTROL PROCEDURES

OBJECTIVE

To provide technical assistance for evaluating the status of, and improvement to, wastewater treatment plant operations in both industrial and municipal sectors.

RELEVANCE

Canadian wastewater treatment systems are experiencing the installation of advanced control systems. Strategies developed at the WTC are available to ensure successful application of these control systems at these candidate plants.

WORK PLAN

1) To respond to requests for guidance from users needing assistance.

2) To assist in the further development and demonstration of a microprocessor-based wastewater treatment plant performance appraisal and energy conservation methodology. This technology, originally implemented at the WTC as part of the plant selection procedure for project 14, would provide the capability of optimizing the performance of existing treatment facilities in terms of plant capacity, energy use, and effluent quality. Two full scale municipal wastewater treatment facilities - one using diffused air aeration and the other using surface aeration have been selected for demonstration of the methodology. Careful attention will be made to accurately assess the costs of implementing this audit so that accurate cost-benefit analyses can be completed.

STATUS REPORT - APRIL 1986 to MARCH 1987

The demonstration of the microcomputer-based plant operation and performance appraisal and energy conservation methodology was carried out at a number of full-scale plants. This procedure had been developed as part of the selection process for the Tillsonburg project and was further demonstrated as a tool for assessing and predicting the potential energy savings and plant operation optimization which can result from the implementation of automated control strategies.

As an example of the results which can be obtained using this technology, for the Kitchener WPCP it was found that the potential for aeration energy savings is in the order of 20 percent. However an even more significant finding was that with minimal upgrade of the aeration hardware and the implementation of automated control to achieve optimal operation of the existing tankage, the plant capacity could be optimized to achieve full

nitrification of loadings projected well beyond the year 2000. It had been proposed that this requirement could only be achieved through a major plant expansion at a much greater cost than the refit options mentioned above. In effect, the operations audit results were used to show how the costly plant expansion could be postponed through more effective use of the existing tankage. Final results of this activity will be available in the first quarter of FY 87/88.

A new activity within this project was initiated to assist in the technical evaluation of dissolved oxygen concentration measuring systems from a number of manufacturers to be undertaken by the Instrumentation Testing Service, Inc. (ITS). The testing and evaluation in accordance with a strict, peer-reviewed protocol under both bench and field conditions will be carried out during FY 87/88. The construction of the bench test apparatus was initiated in February.

Finally, as an ongoing commitment to technology transfer, technical advice and assistance was provided to a number of users of on-line instrumentation and automated control technology in wastewater treatment facilities.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: D.T. Chapman

PROJECT NO. 99716 TEL: 336-4621

ACTIVITY NO: 2400

TITLE: REDUCING IMPACT OF STORM FLOWS ON SECONDARY CLARIFIER PERFORMANCE

OBJECTIVE

1) To characterize the performance of the activated sludge process during storm flows.

2) To establish the effectiveness of step-feeding in activated sludge systems for reducing the suspended solids concentration discharged in the plant effluent during storm flows.

3) To develop an operating strategy for optimizing step-feeding.

RELEVANCE

The performance of activated sludge plants is limited by the escape of suspended solids in the effluent; the majority of the effluent phosphorus and BOD_5 are associated with the suspended solids. Therefore, one of the major objectives in operating an activated sludge plant must be to minimize the escape of suspended solids in the effluent.

One operational technique which can be used to address this is step-feeding. This consists of adding primary effluent at various points along the length of the aeration tank instead of at the head end of the aeration tank as is customary. During periods of hydraulic overloading, the point of addition of the primary effluent is shifted towards the outlet end of the aeration basin. As a consequence, the solids concentration to the final settler is decreased and effluent quality is improved.

The step-feed modification holds the potential for improving effluent quality and reducing variability without requiring expensive plant expansions. Additional information is required to document the potential improvements achieved using step-feed and to optimize the strategy.

WORK PLAN

1) Pilot Plant (PP#1) will be modified to include a new circular final settler and new sensors. (Completion of installation - October 1986.)

2) The upgraded plant will be commissioned by December 1986.

3) Storm flows will be simulated by pumping effluent from storage tanks. The impact of the storm flows will be established with and without step-feeding and a strategy developed for optimizing the benefits achieved by step-feeding. The final report will be available by March 1988.

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Modifications were completed to Pilot Plant #1 to accommodate the proposed research. The plant consists of a 66 m^3 aeration basin compartmentalized into three completely mixed reactors in series and a 3.7 m diameter final settler. To enable storm flows to be simulated, pipes and pumps were added so that final effluent could be stored and recycled back to the aeration tank at a controlled rate. Raw sewage or storm flow (raw sewage plus recycled effluent) can be added to one of the three aeration tanks, but not to combinations of the three.

System response was established as step feeding was introduced in the absence of storm flow loadings. The addition of raw sewage to the second or third aeration basin resulted in a decrease in solids loading to the final settler. However, in each case, high levels of effluent turbidity occurred approximately two hours after the introduction of step feed and persisted for the length of the experiments. The turbidity levels resulted from changes to the flocculation properties of the mixed liquor as step feeding altered the food-to-micro- organism ratio in the aeration compartment preceding the final settler.

The dynamic response of the system to storm flow loadings was characterized in the absence of any corrective action by subjecting the pilot plant to step increases in influent flow rate and monitoring MLSS distribution in the aeration tank and suspended solids and BOD_5 in the effluent from the final settler. The storm flowrates investigated represent final settler overflow rates of 1.96 $m^3/m^2 \cdot h$ and 2.80 $m^3/m^2 \cdot h$. At the lower flowrates, solids were transferred from the aeration basin to the settler, increasing the depth of the sludge blanket, but increasing effluent suspended solids only slightly. As the mixed liquor in the plant settled very well, the sludge blanket rose to within 1.5 m of the final settler weirs without causing a significant deterioration in effluent quality. At the higher overflow rates, solids washout of the sludge blanket occurred within two hours. Combined runs with both step feed operation and storm flow loadings confirmed that step feed prevented plant failure under conditions which would result in solids washout out if no action were taken.

Upon completion, the research will fully document the response of the activated sludge process under step feed, storm flow and combined step feed and storm flow. This information will establish the utility of step feed control for reducing the impact of storm flows.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: D.T. Chapman

PROJECT NO. 99718 TEL: 336-4621

ACTIVITY NO: 2400

TITLE: EVALUATION OF PHOSPHORUS REMOVAL AT FULL-SCALE PLANTS

OBJECTIVE

1) To complete the evaluation of the suitability of full-scale biological phosphorus removal processes for application in Canada, and disseminate the information to potential users.

2) To provide input to a project funded by the Canada/Ontario Agreement (COA) to evaluate the phosphorus removal efficiencies of existing treatment plants in Ontario.

RELEVANCE

Control of phosphorus is required in discharges to receiving waters which are susceptible to eutrophication such as those in the British Columbia Interior and the Great Lakes. Phosphorus removal by chemical addition is widespread in plants in the Great Lakes and consideration is being given to reducing the limits on effluent phosphorus concentration. Information is required to determine the number of plants which could meet the reduced limits and develop cost-effective strategies for meeting the new limits. In addition, there is a need to determine the applicability of biological phosphorus removal under Canadian conditions to provide an alternative to chemical addition.

WORK PLAN

1) Preparation of final report on the evaluation of the performance of the biological phosphorus removal technology at the Kelowna municipal wastewater treatment plant.

2) Provide input to the Canada/Ontario Agreement project via the Liaison Committee and review the interim and final reports. The major study tasks with target completion dates are:

- To review historical data for plants in the four Great Lakes basins to examine strategies for reducing annual phosphorus loadings (March 31, 1986).
- To identify critical factors affecting phosphorus removal efficiencies by conducting a detailed review at selected plants (May, 1986).
- To provide technical assistance at a number of facilities to demonstrate methods for improving phosphorus removal (December, 1986).
- To examine alternative basin-wide phosphorus management strategies for municipal wastewater treatment plants (March, 1987).

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1) A draft report on the Kelowna biological phosphorus removal project was accepted from the contractor. The work demonstrated the feasibility of achieving N & P control under winter operating conditions for municipal sewage. Consistent removal of total phosphorus to values below 1.0 mg/L was not achieved.

2) The review of historical effluent data indicated that basin flows into Lake Erie and Lake Ontario are increasing at a rate of 2.5 percent per year. For the 96 Ontario treatment plants in the Great Lakes basin, 18 require improved performance to meet an annual effluent phosphorus concentration of 1.0 mg/L. Sixty-three plants would require improvements should compliance be based on a monthly average.

Methods for optimizing phosphorus removal efficiency using low capital cost modifications were demonstrated at four treatment plants. Changes included tighter control over coagulant dosage, a better split of recycled digester supernatant streams, and the implementation of a program to control industrial discharges and reduce the concentration of phosphorus entering a plant. In addition, at a one of the plants a detailed review of plant operations and historical data revealed that, because of bottlenecks in a complex sludge management system, high levels of suspended solids are being carried in the aeration tanks. During storm flow periods, solids are washed from the plants, increasing the concentration of particulate phosphorus.

Based on the field study of selected plants, key factors affecting phosphorus removal were found to be chemical dosage and secondary surface overflow rates. Chemical dosage rates must be high enough to maintain a metal to soluble phosphorus concentration of 1.5 mole/mole. At this dosage rate, effluent soluble phosphorus concentrations are less than 0.54 mg/L and total phosphorus concentrations less than 1.0 mg/L. Surface overflow rates for secondary clarifiers must be low enough to prevent high particulate phosphorus concentrations which result from the washout of suspended solids.

Review of activities for the project is conducted by a Liaison Committee consisting of personnel from the Ontario Ministry of the Environment and Environment Canada. The final project report is in preparation and should be released in early fall, 1987.

SECTION: BIOLOGICAL PROCESSES

PROJECT MGR: E.R. Hall

PROJECT NO. 99720

TEL: 336-4715

ACTIVITY NO: 2400

TITLE: FULL-SCALE EVALUATION OF ANAEROBIC TREATMENT SYSTEMS

OBJECTIVE

To evaluate proposals and provide technical assistance to other agencies involved in the implementation of anaerobic treatment technology at full scale.

RELEVANCE

Transfer of information from WTC high rate anaerobic process technology development projects.

WORK PLAN

Support will be provided on an as required basis.

STATUS REPORT - APRIL 1986 TO MARCH 1987

1. Ogilvie Mills, Thunder Bay Ont. [Anamet (anaerobic contact) thermophilic process. Wheat starch wastewater.] E. Hall met with staff of Ogilvie Mills on January 14 to review the last 12 months of operating results for the full scale thermophilic anaerobic treatment system at Thunder Bay. The thermophilic anaerobic reactor is currently at 110% of the design organic loading and is reportedly meeting the MOE effluent discharge criteria. Agreement was reached to compile the results for publication and public distribution.

2. Millbank Cheese, Millbank, Ont. [Completely mixed suspended growth reactor. Cheese whey and washwater.] The performance of the cheese whey digester was improved substantially by the periodic addition of municipal digester sludge. It appears that seeding will be required routinely for successful operation. E. Hall co-authored a paper with G. Adams of Canviro Consultants describing the results of the pilot scale and full scale cheese whey anaerobic treatment studies carried out at the WTC and Millbank Cheese. This paper was presented at the PCAO Seminar on Anaerobic Fixed Film Digestion held in Toronto on November 5, 1986.

3. Metropolitan Authority of Halifax, Dartmouth and the County of Halifax. [Two sludge blanket/fixed-film hybrid reactors. Landfill leachate.] DRECT and WTC staff met with the owner and contractor in Halifax on May 10 to review progress to date in the construction of the DRECT-sponsored anaerobic leachate treatment plant. Monitoring and reporting requirements for demonstration of the facility were also discussed. Construction of the anaerobic portion of the treatment system was completed in March, 1987. Start-up of the entire treatment system is expected to take place in April, 1987.

4. Cavendish Farms Ltd., New Annan, P.E.I. [Covered anaerobic lagoon. Vegetable and potato processing wastewater.] A request was received from Energy, Mines and Resources Canada for WTC staff to provide assistance to the Energy Mines & Resources Canada PEI district office, in directing a performance evaluation program for the bulk volume fermenter. E. Hall reviewed the project proposal and returned comments to EM&R in Charlottetown.

5. Nabisco Brands Ltd., Calgary, Alberta. [Sludge blanket/fixed-film hybrid reactor. Yeast production wastewater.] Construction of the hybrid anaerobic treatment plant was completed and the system was put into operation during the week of May 26, 1986. Because several difficulties were encountered during start-up of this process, it was subsequently decided that a bio-augmentation product, BR-90 (Canber Industries) would be utilized to improve process performance. This product was also the subject of a WTC study (Project 24).

6. Universal Drum/Kenox Corp., Mississauga, Ontario. The Kenox wet oxidation system located at the Mississauga plant of Universal Drum Ltd. is designed to remove 80-90% of the COD in the wastewater produced during the cleaning and refurbishing of 200 liter drums. Kenox is assessing the feasibility of developing a full scale anaerobic treatment system for upgrading the quality of the final effluent produced by the oxidation process. Samples of effluent from the Kenox process were shipped to the WTC for serum bottle testing. Preliminary results indicated that the Kenox effluent contained high concentrations of sulfate which may interfere with methanation.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: R.M. Jones

PROJECT NO. 99721 TEL: 336-4686

ACTIVITY NO: 2400

TITLE: PROCESS MONITORING AND CONTROL
FOR ANAEROBIC TREATMENT SYSTEMS

OBJECTIVE

To develop automated monitoring and control strategies for anaerobic reactors to improve process performance and reliability with toxic and inhibitory industrial wastewaters.

RELEVANCE

Anaerobic biological processes provide an economical alternative for the the treatment of concentrated industrial wastewaters. However, many of these effluents contain complex organic and inorganic components which may be inhibitory to the treatment plant microorganisms. Automated monitoring and control systems could help to ensure smooth start-up and efficient and trouble-free treatment plant operation in these applications. Development of monitoring and control strategies is hampered by a lack of understanding of dynamic and steady state process behaviour and by the limited availability of sensors for the on-line measurement of important process variables.

WORK PLAN

A pilot scale anhybrid reactor fitted with automated monitoring instruments and a real time microcomputer for data acquisition and control was allocated to this project. Experimental modelling has been used previously to partially define the dynamic behaviour of this facility. Experiments will continue to be used in conjunction with mechanistic modelling to further define process behaviour under a variety of conditions. Techniques such as extended Kalman filtering will be developed and demonstrated for the on-line estimation of process variables. Needs for the low-level control of parameters such as pH will be defined and appropriate control algorithms will be developed and demonstrated. Also, the microcomputer-based data acquisition and control software will be further developed to provide a flexible process automation package.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Due to difficulties encountered in understanding the dynamic behaviour of the anhybrid pilot plant during earlier dynamic experiments and due to the relatively large quantities of wastewater required to run the system, a decision was made to use the 55 L ANITRON system supplied by Dorr-Oliver for this study. This reactor was started up in April, 1986 with a feed of pulp and paper wastewater from the MacMillan Bloedel Sturgeon Falls mill.

The ANITRON unit was operated until October with the Sturgeon Falls wastewater. The performance of the reactor was marginal with COD removal

reaching only 30-40% at a maximum loading of 14 kg COD/m^3·d. Because of the poor performance experienced, Dorr-Oliver recommended updating the design of the ANITRON. Design changes included, the installation of a new three phase separater at the top of the reactor, a new smaller sand in the bed, and the addition of a biofilm thickness control pump. The net result of these changes was a reduction in the recycle rates required for fluidization of the bed and an increase in the surface area available for the attachment of biomass.

The ANITRON unit was shut down in late October to make the design changes. The re-designed pilot unit was started up on a grape brandy stillage wastewater from Reider Distillery Ltd. in Grimsby, Ontario. Preliminary performance results on the new system were good - COD removal reached 80-90% after less than 20 days of operation. Increases in loading were limited, however by hydraulic problems in the system. The unit went through several shutdowns to make design changes to eliminate these problems and to make repairs to the older sections of the reactor. By the end of February, however, the system was consistently achieving COD removal efficiencies above 90% at a loading of 12 kg COD/m^3·d.

Coincident with the reactor start-up period, several tasks were completed which are necessary for dynamic experimental work on the system. New gas flow measurement equipment was installed which would allow for the on-line measurement of the wide range of gas flows which could be encountered in the dynamic runs. Infrared carbon dioxide and methane analysers used previously on the anhybrid pilot plant were recommissioned for on-line analysis of the ANITRON biogas composition. A chromatographic analyser for gas phase hydrogen measurement was selected and installed in an on-line mode. The front end data acquisition and control unit was updated from the CBM 8032 based system to a TI/SAFE 8000 system. This change was made to increase the flexibility of the system in automating experimental runs and to increase the portability. Equipment was installed for on-line temperature and recycle control and proportional-integral controllers were designed to provide close regulation of these variables.

A "four population" mechanistic model of the high rate anaerobic process was developed. The model is intended initially as an aid in the dynamic experimental design and will later be used in off-line monitoring and control investigations and for the design of on-line estimation techniques. The model will be calibrated and verified with data from the pilot plant.

The first in a series of screening experiments was conducted in late March in order to establish what level of perturbation would be required to obtain a significant response, and to test the new pilot plant hardware and software. In this test, the reactor loading was instantaneously increased from 10 kg COD/m^3·d to 50 kg COD/m^3.d for a period of 3 hours. Significant responses were recorded for gas flowrate, methane, CO_2 and H_2 gas content, pH, effluent COD, and effluent volatile acids. Also of interest was the observation that most variables returned to near baseline levels within 30 hours of the end of the loading pulse. A higher level of propionic acid persisted for a longer period of time.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: E.R. Hall

PROJECT NO. 99722 TEL: 336-4715

ACTIVITY NO: 2400

TITLE: PILOT SCALE ASSESSMENT OF ANAEROBIC TREATMENT FOR PULP AND PAPER WASTEWATERS

OBJECTIVE

To develop and demonstrate anaerobic treatment processes for application to pulp and paper wastewaters.

RELEVANCE

The recent escalation in the cost of energy has made anaerobic technology very attractive for the treatment of large volumes of wastewater containing high concentrations of BOD. To provide the impetus for implementation of anaerobic treatment in the Canadian pulp and paper industry, Environment Canada recently completed an extensive pilot scale anaerobic testing program with a pulp and paper wastewater. Several companies have now initiated preliminary or detailed planning for similar studies at a number of mill sites. Environment Canada has been requested to provide technical support to the companies involved in these evaluation programs.

WORK PLAN

Technical support provided to the projects indicated below will include proposal review, consultation and advice, and the provision of Scientific Authorities for government funded contracts.

STATUS REPORT - APRIL 1986 TO MARCH 1987

1. MacMillan Bloedel Ltd., Sturgeon Falls, Ont. A 20 m^3 UASB pilot plant was supplied by Paques Lavalin for on-site testing with effluent from an NSSC mill and a hardboard plant. It was put into operation at Sturgeon Falls on May 9, 1986. Over the first 125 days of the study, steady state runs were completed at organic loadings of 5, 10 and 15 kg COD/m^3·d with BOD removal efficiencies of greater than 80%. After the average loading was increased to 20 kg/m^3·d, the UASB reactor encountered problems with foaming in the gas collector, and with the pH control system. Loadings were reduced while a spray chamber was installed on the gas line to prevent plugging of the gas system by foam. Although foaming was controlled by the spray chamber, the UASB reactor recovered slowly from the process upset. Since this slow recovery is uncharacteristic of anaerobic systems, it was hypothesized that the wastewater contains toxic material which is inhibiting the Biopaq process. Serum bottle toxicity testing was initiated by Paques Lavalin to test this hypothesis.

It was also agreed that sufficient data has been obtained to confirm that 15 kg COD/m^3·d is the design loading figure to be used for a full scale system at Sturgeon Falls. This loading represents a 50% increase over that assumed for the preliminary design and associated cost estimates.

A paper entitled "Evaluation of Anaerobic Treatment for NSSC Wastewater" describing the WTC pilot testing results in the MacMillan Bloedel Sturgeon Falls program, was presented at the 1986 TAPPI Environmental Conference in New Orleans by A. Chmelauskas of MacMillan Bloedel. A shortened version of the paper was also published in the TAPPI Journal.

2. Environment Canada - PAPRICAN Study, Spruce Falls Power and Paper Ltd., Kapuskasing, Ont. An anaerobic pilot plant constructed at the WTC was shipped to Kapuskasing on October 7, 1986. The facility was seeded and put into operation on October 22 with a feed of TMP whitewater. At the beginning of January, the WTC shipped approximately 200 litres of granular sludge to Kapuskasing for a second seeding of the hybrid pilot plant. The sludge was pumped into the methane reactor and flows were gradually re-established to bring the overall system HRT to 1.1 days, and the organic loading to 4.1 kg COD/ $m^3 \cdot d$. Magnefite evaporator condensate was subsequently introduced as part of the feed , and the overall process HRT was reduced to 0.75 days (8.0- 9.0 kg COD/$m^3 \cdot d$) with a mixture of 80% TMP whitewater and 20% magnefite condensate feed. COD removal efficiencies have remained about 55%. These operating conditions were maintained while the mill installed a dilution water line required for some of the planned experimental runs.

3. Quesnel River Pulp Co., Quesnel, B.C. A contract was awarded to Beak Consultants of Toronto for review of the WTC-generated treatability data on the CTMP and TMP effluents produced at QRP. The final project report was delivered to the WTC on September 15. In January 1987, Paques Lavalin of Toronto was announced as the successful bidder for the next phase of the study at the QRP mill site.

4. Consolidated-Bathurst Inc., Bathurst, N.B. Pilot-scale commercial high rate anaerobic reactors were evaluated at Bathurst for treatment of NSSC and peroxide bleached CTMP effluent. Discussions were held with the process consultant for the Bathurst anaerobic pilot study to clarify the treatability results obtained during the Bathurst study with CTMP wastewater alone. Several samples of Bathurst wastewater were shipped to the WTC for serum bottle testing and an evaluation of a chemical stimulation procedure provided to the WTC by Mr. T. Welander of the Technical University of Lund in Sweden. The results provided no evidence of an improvement in CTMP wastewater treatability with the Swedish procedure tested. A decision on the successful bidder for a full scale anaerobic treatment system at Bathurst is expected to be made within 2 months.

5. Lake Utopia Paper Ltd., St. George, N.B. Paques Lavalin of Toronto was announced as the successful bidder for a pilot-to-full scale program for anaerobic treatment of wastewater from Lake Utopia's NSSC mill.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: R.M. Jones

PROJECT NO. 99723 TEL: 336-4686

ACTIVITY NO: 2400

TITLE: ANAEROBIC PRETREATMENT OF INDUSTRIAL WASTEWATER FOR DISCHARGE TO A MUNICIPAL WATER POLLUTION CONTROL PLANT

OBJECTIVE

To evaluate the suitability of anaerobic technology for the pretreatment of wastewater from an multi-industry complex prior to discharge to a municipal water pollution control plant at Portage la Prairie, Manitoba.

RELEVANCE

Municipalities faced with growing industrial loadings to a municipal water pollution control plant (WPCP), have two options for addressing the problem. The traditional approach has involved expansion of the WPCP to accommodate the increase in loading. An alternative approach is to provide pretreatment of the industrial component at the plant site to reduce the loading on the municipal WPCP. At Portage la Prairie, the wastewater from several food processing plants could be combined and pretreated with an anaerobic process. The efficacy of this approach and its effect on the municipal WPCP requires assessment.

WORK PLAN

In a cooperative program with the University of Manitoba and the Manitoba Water Services Board, the WTC will arrange for the location of mobile anaerobic pilot plant facilities at Portage la Prairie. A 6 to 12 month testing program will examine the degree of treatment attainable for the combined effluent from the industrial park. In addition, the treatability characteristics of the anaerobic effluent will be assessed to determine its impact on the existing deep shaft process at the municipal WPCP.

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In April, a contract was issued to Canviro Consultants by the Manitoba Water Services Board, on behalf of the City of Portage la Prairie and Environment Canada, to carry out the the anaerobic treatability study of the industrial park wastewater at Portage la Prairie. The Agriculture Canada mobile anaerobic pilot plant and a supporting laboratory trailer was moved to the site and put into service near the beginning of May.

A wastewater characterization program conducted as part of the contract included sampling of the industrial park lift station wastewater on a daily basis from May until January, and two periods of 24 hour diurnal sampling of the two major contributors to the wastewater loading at the industrial park.

The upflow sludge blanket and the random packed anhybrid reactors in the mobile pilot plant were started up in May. Both of these reactors achieved a 70-80% COD removal efficiency during the early stages of the program. However, these removals were achieved at loading rates of less than 2 kg COD/m^3.d. Increases in loading were limited by problems in maintaining an adequate sludge bed in the reactors. An oriented media anhybrid reactor was started up in September. Problems in retaining biomass were also observed in this system.

In October, the three reactors were seeded with granular sludge provided by MacLaren Engineers Inc. Performance of the oriented media and random media anhybrid reactors improved after the seeding. The performance of the upflow sludge blanket reactor improved at first but then slowly declined due to wash-out of the biomass.

Due to its declining performance and as a time and cost saving measure, the upflow sludge blanket reactor was shut down on December 8. The remaining reactors were re-seeded with the sludge from the sludge blanket reactor.

With higher than expected maintenance and repair costs in the pilot plant trailer resulting largely from high levels of hydrogen sulphide gas being produced from the wastewater and damaging equipment, funding for the operation of the trailer was exhausted by the end of December. Since loadings to the reactors had not been sustained at what was expected to be reasonable design levels for a full scale anaerobic system and since the impact of possible intermittent flows at the lift station had not been addressed, the Manitoba Water Services Board and Environment Canada decided to provide additional funding which would extend operation of the pilot plant system to Jan. 31.

The flow to the reactors was shut down during a two week Christmas shut down of the industries at the Portage industrial park. After the re-start of the reactors in early January, loading increases were implemented as quickly as possible. The oriented media anhybrid reactor HRT was maintained at 10 hours throughout the month giving a maximum loading of about 9 kg COD/m^3·d. The random media anhybrid HRT was reduced to 8 hours giving a maximum loading of about 12 kg COD/m^3·d. A planned loading of 13 kg COD/m^3·d was not reached due to lower than expected wastewater concentration at the lift station. The COD removal efficiencies during the month ranged between 60 and 70 %. The pilot plant was shut down on January 30.

A specification document and a data package was compiled by Canviro in March and sent to anaerobic suppliers chosen to bid on the Portage la Prairie project. The specification document stated all items that a detailed technical and cost proposal from each supplier should cover. Pricing was requested on a turnkey basis with the supplier responsible for design, construction, construction management, start-up and operator training. The data package included all data collected during the treatability demonstration and during the wastewater characterization program. A final recommendation of a supplier will be made based on the submitted proposals.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: E.R. Hall

PROJECT NO. 99724 TEL: 336-4715

ACTIVITY NO: 2400

TITLE: EVALUATION OF HIGH RATE ANAEROBIC PROCESSES

OBJECTIVE

To complete the documentation of several anaerobic treatment studies sponsored by Environment Canada and other agencies.

RELEVANCE

Environment Canada has sponsored several projects on anaerobic treatment of high strength industrial and municipal wastewaters. Experimental work under these programs will be completed by early FY 1986/87, providing extensive data on process assessment, wastewater treatability and reactor operating strategies. Results from these studies will be compiled and summarized in several forms for public distribution.

WORK PLAN

Technical reports and/or papers will be prepared on the following subjects by WTC staff:

- .treatment of wheat starch wastewater
- .treatment of NSSC/Hardboard mill wastewater
- .treatment of thermal sludge conditioning liquor
- .treatment of brewery wastewater
- .treatment of wet corn milling wastewater
- .treatment of cheese plant wastewater
- .anaerobic trickling filter performance

Technical reports prepared by other agencies will be reviewed and edited by WTC staff. These reports will include:

- .design and performance of anhybrid reactors - University of Manitoba
- .anaerobic treatment of peat pressate - Ontario Research Foundation
- .anaerobic treatment of coal liquefaction condensate - Dearborn Environmental Consultants
- .enhanced anaerobic biodegradability with WETOX pretreatment - Ontario Research Foundation

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The results of several WTC anaerobic programs were documented in a number of publications and presentations. This material is summarized in the bibliography accompanying this report.

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A report on the results of the serum bottle testing phase of a microbial product manufactured by Canber Industries of Nanaimo B.C. was completed. This bio-augmentation product is being evaluated at the WTC for use as an additive to improve the start-up of high rate anaerobic reactors in locations where municipal digester sludge is not readily available. The first phase of the continuous anaerobic reactor startup study was initiated on February 25. The objective of the first phase is to evaluate the efficacy of polymer addition to reactors seeded with municipal anaerobic digester sludge. The polymer is expected to result in better sludge settleability and reduced startup times.

On November 6, 1986, the WTC hosted a Technology Transfer Workshop on Laboratory Scale Anaerobic Treatability Testing Techniques which included three papers and an audio-visual presentation prepared by WTC staff. The workshop was attended by approximately 45 participants from Canada and the U.S. Copies of the proceedings are available from the WTC.

Through participation in the activities of the Program Committee, WTC staff assisted in the preparations for the 5th International Symposium on Anaerobic Digestion to be held in June 1988 in Bologna, Italy.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: E.R. Hall

PROJECT NO. 99729 TEL: 336-4715

ACTIVITY NO: 2300

TITLE: ANAEROBIC TREATMENT OF COMPLEX INDUSTRIAL WASTEWATERS

OBJECTIVE

To develop appropriate energy-efficient anaerobic technology for treatment of complex organic waste streams produced by Canadian industries.

RELEVANCE

Anaerobic technology provides the potential for achieving cost-effective wastewater treatment in many industrial sectors. For those industries whose effluents contain toxic or refractory components, additional information is required for successful process design and operation. For example, in the the pulp and paper industry, little data are available on the anaerobic biodegradability of waste streams from existing and novel pulping technologies. In addition, experimental data are needed to determine the anaerobic process design requirements for achieving effluent toxicity levels specified by the federal pulp and paper effluent regulations.

WORK PLAN

Under the direction of an industry/government advisory committee, wastewater samples from pulp and paper mills will be assessed with serum bottle anaerobic assay techniques. The results will be used to establish priorities for continuous flow studies using WTC pilot scale or laboratory scale equipment for toxicity removal experiments. The serum bottle technique will also be used to assess the effectiveness of pre- and co-treatment technologies for improving the reliability and efficiency of anaerobic treatment processes. It is anticipated that similar work will be undertaken with selected wastewaters produced in other industrial sectors.

STATUS REPORT - APRIL 1986 TO MARCH 1987

A paper describing the serum bottle anaerobic testing technique developed at the WTC was presented by L. Cornacchio at the 21st Canadian Symposium on Water Pollution Research, in Burlington on April 30. A first draft of the manuscript was prepared and submitted for review by L. Cornacchio.

Routine chemical analysis and anaerobic bioassay testing of the 43 Canadian pulp and paper mill effluents was completed in November 1986. The data from this study are presently under review for preparation of the project report. A summary of the data was included in a paper presented by E. Hall at the 73rd Annual Meeting of the CPPA Technical Section in Montreal on January 30. At the request of TAPPI Environmental Conference organizers, the same paper was forwarded to TAPPI for pre-printing in the conference proceedings prior to presentation at the 1987 conference in April.

Results of the pulp and paper screening program and objectives for the next phase of research were reviewed and approved at a meeting of the Technical Advisory Committee in Montreal on January 27.

SECTION: BIOLOGICAL PROCESSES

PROJECT MGR: H. Melcer

PROJECT NO. 99730

TEL: 336-4546

ACTIVITY NO: 2400

TITLE: NEW BIOLOGICAL METHODS FOR TOXIC CHEMICAL DEGRADATION

OBJECTIVE

To assess the potential of biological reactor systems in removing trace organic contaminants.

RELEVANCE

Studies that have been carried out to date on the biological removal of trace organic contaminants have either been at shake flask level or have been conducted as chemostat experiments. Little work has addressed specific contaminant removal in continuous flow biological reactors. Volatile organics are one group of trace contaminants of concern. Their loss in a treatment system occurs either by stripping or biodegradation although the proportion attributed to each mechanism is not known. Ideally, the reactor should be conditioned to remove the volatiles by biodegradation.

WORK PLAN

Work on the treatability of trichloroethylene completed in 1985/86 will be reviewed to determine how to formulate further work on the removal of volatile organic contaminants from municipal wastewaters.

STATUS REPORT - APRIL 1986 to MARCH 1987

Papers on the fate of trichloroethylene, 4,6-dinitro-o-cresol, and pentachlorophenol in activated sludge systems were presented at the 21st Canadian Symposium on Water Pollution Research (April, Burlington, Ontario) at the International Conference on Innovative Biological Treatment of Toxic Wastewaters (June, Washington, D.C.), and at the Annual Water Pollution Control Federation Conference (October, Los Angeles) respectively.

Additional bench scale studies on the removal of volatile organic contaminants from municipal wastewaters were postponed until next fiscal year, as the funds were not available to complete the Toxic Chemicals Laboratory being constructed to meet the health and safety codes.

SECTION: BIOLOGICAL PROCESSES PROJECT MGR: H. Melcer

PROJECT NO. 99732 TEL.: 336-4546

ACTIVITY NO: 2200

TITLE: TECHNOLOGY SUPPORT TO REGIONAL OFFICES & FEDERAL FACILITIES

OBJECTIVE

To provide technical support to EPS regional offices and Federal facilities with respect to biological technology for the treatment of municipal and industrial wastewaters.

RELEVANCE

In support of all departmental priorities by providing technical support to regional offices and Federal facilities with respect to biological treatment processes.

WORK PLAN

To provide technical advice and program review on an as required basis.

STATUS REPORT - APRIL 1986 to MARCH 1987

Assistance was provided to the Newfoundland MOE on the control of odours from an aerobic digester facility.

An economic feasibility study of using sequencing batch reactor technology in the proposed upgrading of the Banff STP was carried out for the Alberta Office of C&P. Further process options were evaluated in December, January and March.

Recommendations were made through Vancouver C&P staff to Chatterton Chemical in Ladner regarding the operation of their wastewater treatment plant. Although Chatterton staff were advised to minimise influent variability and implement SRT control, there appears to be no incentive to optimize the treatment plant operation because the B.C. MOE have relaxed Chatterton's discharge permit.

A diskette was received containing data from a tracer study conducted at the Whitehorse lagoons. The data were analyzed using several techniques. A memo was provided to C&P staff in Whitehorse summarizing the results and providing recommendations for future work.

The process design of the Springhill Farms, Neepawa wastewater treatment facility was reviewed. Comments were provided to the C&P District Office in Winnipeg.

Options for treating the wastewater from Garden Province Meats in Charlottetown were evaluated for the Atlantic Region. There were inadequate wastewater characterization data available upon which to make recommendations.

PROJECT STATUS REPORTS - RESIDUE MANAGEMENT SECTION

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: T.W. Constable

PROJECT NO. 99834

TEL: 336-4716

ACTIVITY NO. 2400

TITLE: TOXICS IDENTIFICATION AND MOBILITY IN SLUDGES

OBJECTIVE:

1. Develop a data base on toxics accumulation and mobility in sludges.
2. Provide technical and analytical support to the Federal/Provincial/Industry Working Group on Criteria and Lists, on characterization of contaminant leaching from hazardous wastes.

RELEVANCE:

Waste disposal sites have been identified as major contributor of toxics entering the ecosystem. Leaching tests can be used as indicators of the potential leachability of a waste and for comparisons among different waste types and forms.

WORK PLAN:

1. Continue development of the data base using the leaching protocol on a variety of wastes, especially those identified in other C&P programs as requiring leachability characterization.
2. Provide technical support to the Federal/Provincial/Industry Working Group on Criteria and Lists.
3. Provide support to WMD regarding leaching tests and hazardous waste classification.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Generic Leaching

Gold Milling Wastes: The experimental program and all analyses for this project were completed early in June of 1986. The report entitled "Evaluation of Contaminant Leachability from Gold Milling Wastes" completed a peer review and was submitted for inclusion in the manuscript series in early February of 1987. This report is supplemental to the report entitled "Evaluation of INCO's SO_2/Air Process for the Removal of Cyanide and Metals from Gold Milling Wastes".

Aluminum Potliner Wastes: C&P Pacific Region shipped aluminum potliner wastes to WTC in early November of 1986. WTC staff developed an experimental program to evaluate the leachability of contaminants from the wastes under various leaching conditions. The experimental program was completed in late January of 1987. Most of the analytical results have been received and processed, however, due to problems with the fluoride analyses, the final report has been delayed. A draft of the report should be ready in late April of 1987.

Coal/Oil Co-processing Sludge: A sample of the sludge was received from Energy, Mines and Resources in February of 1987. The sample was submitted for organic and inorganic contaminant analyses. The analytical results were required to assist with the development of an experimental program for the evaluation of contaminant leachability from the sludge. The experimental program was completed in late March and a report will be available by mid-summer 1987.

FMC Chlor-Alkali Sludge: Sludge samples were received in March of 1987 and submitted for analyses of priority heavy metals including mercury. The experimental program was completed in mid-March 1987.

Windermere Basin Study (MOE)

The first draft of the final report for the Windermere Basin Technical Advisory Committee was prepared in April. The findings of the study were presented to this committee at the Ontario MOE offices (West Central) on April 25 by P. Côté and S. Sawell, and to the Hamilton-Wentworth Regional Engineering Committee at Hamilton City Hall on May 12 by S. Sawell. The report was revised based on the comments arising from these meetings, and the final report was submitted to the Windermere Basin Technical Advisory Committee on May 16. A composite sample of the sediments in the lysimeters was collected for the Ontario MOE before the systems were dismantled.

Expert System for TDGA Hazardous Waste Classification

During April to September, a study was conducted for the WMD to provide a preliminary assessment on the usefulness and applicability of knowledge-based expert systems for classifying hazardous wastes. Using Texas Instrument's Personal Consultant Plus software program, an expert system was developed to classify wastes according to the Transportation of Dangerous Goods Regulations. The study indicated that expert systems of this type would be very useful for assisting regulators in developing hazardous waste regulations, and for assisting waste handlers in assessing hazardous waste streams according to the developed regulations.

Expert System for Assessing Solid Waste Leaching and Disposal

In November, a U/P entitled "Expert System Software Development for Assessment of Solid Wastes Leaching and Disposal" was received. The study proposes to develop an expert system which will assist government agencies and industries to assess a solid waste in terms of its leaching characteristics, leachate treatment and suitability for disposal in a landfill.

The proposal was discussed with the US EPA's Robert S. Kerr Environmental Research Laboratory (RSKERL), the Oak Ridge National Laboratory (ORNL), and with R. Jackson, a member of the CCREM Working Group on Waste Site Monitoring Methodologies, who is preparing a report on current and recommended future research in this area for the CCREM Task Force on

Research Coordination. Copies of the proposal were also sent to the Netherlands Energy Research Foundation, the Canadian Electrical Association, IPB and the C&P Regional Offices for review. The general response to the proposal was very favourable, and it was felt that this was definitely the direction that future work in waste leachability should be taking. To date, however, no financial support for this proposal has been received.

Transportation of Dangerous Goods Regulations

Meetings of the Working Group on TDG Hazardous Wastes were held in Ottawa on Oct. 27 and 28, and in Halifax on March 4 and 5. As follow-up activities of the meetings, the "Terms of Reference for the Development of an Analytical Methods Guide for the Proposed TDG Regulations Leachate Test", the revised TDG Manifest form, and the report "Leachate Tests Evaluation: Background Review to Support TDGR Hazardous Waste Definition", were reviewed for the Waste Management Division, IPB.

SECTION: RESIDUE MANAGEMENT PROJECT MGR. H.W. Campbell

PROJECT NO. 99836 TEL: 336-4717

ACTIVITY NO. 2400

TITLE: PROCESS CONTROL - SLUDGE CONDITIONING/DEWATERING

OBJECTIVE:

To develop an automatic control strategy for sludge conditioning and dewatering based on the measurement of the rheological properties of sludge, to develop a commercial prototype to accomplish this and to demonstrate this strategy at a full scale dewatering facility.

RELEVANCE:

The automatic control of sludge conditioning and dewatering processes has been hampered by the lack of physical measurements available to describe sludge properties. Rheology has been shown to be capable of identifying changes in both sludge solids concentration and sludge dewatering characteristics. The control of chemical addition based on rheological properties has the potential to decrease polymer utilization and improve dewatering performance.

WORK PLAN:

1. Provide technical support and experimental facilities for the PILP contract.
2. Operate the 0.5 m belt press at the WTC to test each stage of development of the prototype.
3. Conduct a sampling program at 3 or 4 sewage treatment plants to determine sludge variability (June 1986).
4. In conjunction with the PILP contractor, identify the site for full scale evaluation of the system (September 1986).
5. Participate in the demonstration of the control strategy using the commercial prototype (March 1987).

STATUS REPORT - APRIL 1986 TO MARCH 1987

Development of the prototype controller was completed in the early part of 1986 and all components were tested on the 0.5m belt press at the WTC. Based on these results, the second prototype i.e. the field model, was developed.

In preparation for the demonstration phase, a sampling program was conducted at three plants (London, Hamilton and Guelph) to measure the variability in sludge characteristics. Hamilton and London were sampled hourly over a twenty-four period while Guelph was sampled hourly over an eight hour period on two consecutive days. The data was summarized, a report prepared for Zenon commenting on the technical suitability of each plant as a potential site for the demonstration phase and as a result, Guelph was selected. The most surprising piece of data was the range in belt press cake solids observed. In the worst case, the cake solids ranged

from 15.5% to 31.4%. The sampling program for the development of a data base on sludge variability was subsequently increased to include three sampling periods at each of the Hamilton, Guelph and London plants.

The field model of the sludge conditioning controller was completed in September and exhibited at the annual WPCF equipment show in Los Angeles. Response to the exhibit was very positive with several companies indicating an interest in testing a unit when one becomes available.

The field model was installed in Guelph on a 3 metre Komline-Sanderson belt press in early November. Initial efforts concentrated on data collection only and the results appeared to correctly identify the observed operating conditions. Preliminary attempts at control were hampered by unpredictable variations in the sludge flow to the press i.e., from 3 to 8 L/s. Since the press was not capable of operating under this type of flow pattern, the sludge feed pump was replaced by one with a constant feed rate. Tuning of the system, including minor software modifications, continued through January and several demonstrations were held to show treatment plant operators, consultants and equipment suppliers how the system operated. The evaluation period of the program was initiated in February and is still underway. A preliminary comparison between two typical operating days (manual versus automatic) was recently carried out. The automatic control day at an average polymer dosage of 4.29 kg/t showed a net polymer saving of 1.43 kg/t or 25% over that of the manual control day at 5.72 kg/t. The only significant problem appears to be the controllers inability to correctly interpret wide swings in feed solid concentrations eg. from 1.5% to 6.0%. This has been resolved by sampling the feed sludge before and after polymer addition. This modification is currently being evaluated.

The support equipment for data collection by the WTC was installed with mixed results. The computer and front end functioned as expected. Reliable operation of the Monitek solids sensors for both the feed sludge and the effluent solids was finally achieved. The Detflow meters did not work satisfactorily and data from Guelph's Polysonic meters were used to measure the sludge flow rate.

A licencing arrangement between Zenon and CPDL was reached to market the technology as the Zenon Sludge Conditioning Controller (SCC).

A paper entitled "An Instrument for Automated Control of Sludge Conditioning" was prepared by WTC and Zenon and was presented at the 9th Canadian Symposium on Wastewater Treatment in November 86, and at the Annual CPPA Conference, January 87.

SECTION: RESIDUE MANAGEMENT PROJECT MGR: M.D. Webber

PROJECT NO. 99837 TEL: 336-4519

ACTIVITY NO. 2400

TITLE: LAND APPLICATION OF SEWAGE SLUDGE

OBJECTIVE:

To develop and demonstrate technology with a view to promoting land application of sludge as an environmentally sound management practice.

RELEVANCE:

Roughly 40% of Canada's sludge is land applied and this utilization option supplies much needed nutrients and humus to agricultural soil. However, continued technology development is required to assure that the negative environmental impact is minimized.

WORK PLAN:

1. To complete analysis and interpretation of WTC lysimeter data and to complete the preparation of manuscripts for publication in scientific journals.
2. To conduct laboratory studies of heavy metal solubilities in the lysimeter soils.
3. To monitor the progress of the Ridgetown College compost utilization study.
4. To provide technical support to DRECT funded demonstration studies (CANVERT).

STATUS REPORT - APRIL 1986 TO MARCH 1987

A fourth draft final report for the Ridgetown College land application of compost study was reviewed and returned to the project leader, Dr. C.S. Baldwin for revision. The report should be completed early in fiscal 1987-88.

The lysimeter study of hybrid poplar fertilization with DuPont Maitland sludge was completed June 1986, however, a report has not been prepared.

WTC are providing technical input into an experimental project to determine whether effluent can be stored during winter as snow without representing an unacceptable environmental hazard. The project is being conducted at Kamloops B.C. by NovaTec Consultants Inc.

Plans have been formulated for greenhouse-scale study of the root-zone artificial marsh system for wastewater treatment. The study will be initiated early in fiscal 1987-88.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: M. Latham

PROJECT NO. 99838

TEL: 336-4720

ACTIVITY NO: 2400

TITLE: THERMAL CHARACTERIZATION OF SLUDGE STABILITY

OBJECTIVE:

To assess the capability of thermal analytical techniques (TGA, DTA, DSC) to characterize sewage sludge stability.

RELEVANCE:

The stability of sewage sludge is an important parameter in determining the suitability of various management options. At the present time there is no universally acceptable method of characterizing stability. Thermal techniques may provide such a universal method.

WORK PLAN:

Using thermal techniques such as TGA, DTA and DSC, characterize a variety of sewage sludges (raw primary, WAS, digested, composted, etc.) to establish a data base. Attempt correlation of thermal characteristics to conventional parameter such as VS reduction, with the aim of establishing criteria for determining stability.

STATUS REPORT - APRIL 1986 TO MARCH 1987

The Du Pont 9900 Thermal Analyzer System was installed and hooked-up to the existing modules. The operation of the device is similar to that of the previous system (Du Pont 1090) but the analysis software is much more advanced.

Fifteen samples of a raw and a digested municipal sludge were obtained from five different sites and prepared for methods development.

Most of the experimental work has been directed towards developing a standardized methodology for conducting DSC and TGA analyses on sludges. Three sets of five replicate runs were completed for sample sizes of 10, 15 and 20 mg. The reproducibility of the runs was quite acceptable and when the output was normalized i.e. reported in terms of watts per gram, the influence of sample size was relatively small. Based on the work to date standard methods for conducting TGA and DSC analyses on sewage sludges have been developed.

Experimental program 38TGA.01 was initiated with five of the fifteen sludge samples collected. Using the standard TGA method, the aim will be to correlate thermal properties with sludge stability.

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In addition, samples of the 14 sludges tested (in the oil from sludge program) will be analyzed by TGA and DSC using the standardized procedure. Specific thermal characteristics will then be correlated with the oil yields generated by the bench-scale reactor in an effort to develop a method for predicting oil yield based on the thermal properties of the sludge.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: P.L. Côté

PROJECT NO. 99841

TEL: 336-4605

ACTIVITY NO. 2200

TITLE: TECHNICAL SUPPORT: QUEBEC REGION

OBJECTIVE:

To provide technical support to C&P Quebec Region and the Province of Quebec with respect to Sludge Treatment Utilization and Disposal.

RELEVANCE:

Environment Quebec has embarked on a major water pollution control program in both the municipal and industrial sectors. The opportunity for technology transfer is great and WTC must be in a position to provide this technical support.

WORK PLAN:

Provide technical support as required. Some specific, identified activities include:

1. Support activities related to simulation of wastewater treatment plants.
2. Investigate potential to provide input to MUC on sludge dewatering/incineration technology.
3. Provide support regarding design, operation, etc. of new treatment plants.

STATUS REPORT - APRIL 1986 TO MARCH 1987

T.R. Bridle made a presentation on RMS activities to a group of Quebec Ministry of Environment personnel on October 22. This related to the upcoming joint Canada/Quebec technology development/assessment program.

H.W. Campbell, with personnel from Gendron Lefebvre, visited the CRIQ press in Montreal on November 11. The press, operating on a mixture of primary sewage sludge plus water treatment sludge (2-3% TS) was capable of achieving cake solids of 35-45%. Evaluation of the press on municipal sludge was conducted under the Gendron Lefebvre U/P. Results indicate that raw mixed and digested mixed sewage sludges can be dewatered to between 28 and 45% cake solids, depending on sludge throughput rate.

M. Webber met, November 20, with R. Zalloum (Quebec Region) and representatives of the College de la Region de L'Amiante to discuss reclamation of Thetford Mines mine tailings using municipal sewage sludge. Studies begun early in 1986 have resulted in development of methods to grow several plant species in the tailings. Further work is required to determine the persistence of plants in the tailings and to test field-scale reclamation methods.

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T.R. Bridle, B.E.Jank and B.A. Monaghan participated in the 25th Annual AQTE Conference by providing support to the Environment Canada display. Process control of sewage treatment plants and the oil from sludge technology were displayed.

WTC is also providing support to C&P Quebec Region and MINVEQ concerning land application of municipal sludge in the Communaute Regionale de l'Outaouais (CRO).

P. Côté met with P. Lavallée to discuss MINVEQ input to the development of a dynamic simulation model for wastewater treatment, being conducted via the U/P submitted by Dr. G. Patry at McMaster University.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: P.L. Côté

PROJECT NO. 99842

TEL: 336-4721

ACTIVITY NO: 2200

TITLE: TECHNICAL SUPPORT: HAZARDOUS WASTE MANAGEMENT

OBJECTIVE:

Provide technical advice and support to IPB, Regions and Provincial agencies with respect to technology for hazardous waste management.

RELEVANCE:

Management of hazardous wastes in an environmentally sound manner is mandatory. Numerous site specific solutions are being sought, as are criteria for establishing acceptable technology for integrated facilities.

WORK PLAN:

1. To liaise with RRETC regarding lab-scale incineration research and interact with USEPA, UDRI and AEC.
2. Provide assistance and advice to P&YR regarding PCP waste management practises.
3. Continue support to AR regarding remedial action at SYSCO and treatment of lime sludges.
4. Continue support to OWMC and MOE.
5. Interact with WMD of IPB regarding waste management technologies.
6. Advice to OR regarding management of dredged spoils.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Staff provided considerable technical advice and support on various aspects of hazardous waste management to C&P Regional staff, provincial agencies, crown corporations, research groups and the public at large during FY 86/87. These activities included assisting IPB and EPS-OR to define BPT for MISA industrial sectors, participating in the DOE Review Group for Port Granby Decommissioning, acting as a project advisor to a Canadian Electrical Association study to characterize circulating bed AFBC solid wastes, assisting IPB to develop a work plan for a Dearborn study involving leachability testing on circulating bed AFBC solid wastes, providing technical and analytical support to the SYSCO TAR Pond Remediation program, and assisting IPB in the assessment of Duffin Creek STP incinerators.

Significant support was provided to C&P Atlantic Region regarding the SYSCO Tar Pond Remediation Program. Terms of Reference for the Remedial Action Plan were reviewed and the appropriate input provided. Samples of Tar Pond Sediments were analysed for PAH's and HNC's, to identify compounds requiring monitoring during the clean-up. Eleven PAH's, at a total concentration of 3500 µg/g and 15 HNC's, at a total concentration of 230 µg/g were identified.

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Support was also provided to C&P P&YR regarding potential use of 2-(thiocyanomethylthio)benzothiozol (TCMTB) as a replacement for PCP in the wood protection industry. Preliminary laboratory data indicate no PCDD or PCDF formation on combustion of industrial grade TCMTB.

Several papers and reports on various aspects of hazardous waste management were published or accepted for publication during FY 86/87. The paper "The Effect of Three Sludge Processing Operations on the Fate and Mobility of Trace Organics in Municipal Sludges" was published in the March 1986 issue of Environmental Technology Letters. The paper "Trace Element Leaching in Bench-scale Recirculating Ash Transport Systems" was published in the April 1986 issue of Canadian Journal of Civil Engineering. The paper "Acidification and Radionuclide Leaching in Unsaturated Uranium Mill Tailings" was presented at the Second International Conference on Radioactive Waste Management, Winnipeg, Sept. 7-11, 1986, and published in the Conference Proceedings. The paper "An Evaluation of Cement-based Waste Forms Using the Results of Approximately Two Years of Dynamic Leaching" was accepted for publication in Nuclear and Chemical Waste Management. The paper "Laboratory Evaluation of AFBC Solid Waste Properties" was accepted for publication in the Canadian Journal of Civil Engineering. The paper "Leachability of Solidified $(Ba,Ra)SO_4$ Sediments in Simulated Settling Ponds" was accepted for presentation at the 42nd Annual Purdue Industrial Waste Conference, May 12 - 14, 1987.

The reports published during FY 86/87 were "Contaminant Solubilization in Bench-scale Recirculating Ash Transport Systems" (Report EPS 3/PG/5), "Development and Applications of a Multiple-batch Leaching Procedure" (Report EPS 3/AT/1), "Evaluation of Solid Residues from Atmospheric Fluidized Bed Combustion, 1983/84" (Report EPS 3/PG/7), and "Evaluation of Solid Residues from Atmospheric Fluidized Bed Combustion, 1984/85" (Report EPS 3/PG/8). The report "Leachability Of Radioactive Constituents from Uranium Mine Tailings - Final Report" was completed and will be published in April, 1987.

SECTION: RESIDUE MANAGEMENT SECTION PROJECT MGR. P.L. Côté

PROJECT NO. 99843 TEL: 336-4605

ACTIVITY NO: 2400

TITLE: TEST METHODS FOR SOLIDIFIED WASTE CHARACTERIZATION

OBJECTIVE:

1. To develop, validate and standardize test methods for the characterization of solidified wastes.
2. Development of a solidified waste characteristics data base for use in establishing performance criteria.

RELEVANCE:

Solidification technologies have the potential of reducing leaching of hazardous constituents from wastes disposed on land. This project will help to determine the best available technology and establish performance criteria.

WORK PLAN:

1. Complete evaluation of the solidified waste assessment protocol in the cooperative project with the vendors and with USEPA, AEC and IPB (February 1987).
2. Pursue standardization of the assessment protocol test with ASTM Committee D34 on Waste Disposal.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Coop Study

Physical testing and leaching results for all five wastes have been distributed to the industrial participants.

The compiled data from testing have also been sent to Alberta Environmental Centre (AEC) and Waterways Experiment Station (WES) from the Wastewater Technology Center (WTC) for review, and use in writing papers for the Hazardous Waste Symposium in Atlanta. Comments are awaited.

All raw waste analyses and QA/QC data have been received at WTC, and are being compiled.

Waste 4 and 5 testing data have been sent to A. Roy at Louisiana State University, for assistance in writing the report of the SEM and XRD characterizations.

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ASTM Multiple Sequential Batch Leaching Procedure Round-Robin Study

The round-robin study is being co-ordinated by staff at the Western Research Institute in Laramie, Wyoming. The project was initiated in October of 1986 and WTC's laboratory work was completed in mid-October. In addition to providing technical support for the project, WTC was also asked to comment on the proposed procedures. WTC analytical results and the comments were sent to WRI in late November. Results from the first part of the study were discussed at the ASTM meetings in Florida in November. Revised procedures were distributed to all participants in January of 1987, however, the test samples did not arrive until late March. The laboratory work should be complete in early April and the analytical results are expected to be complete sometime in mid to late April.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: P.L. Côté

PROJECT NO. 99844

TEL: 336-4605

ACTIVITY NO: 2200

TITLE: TECHNOLOGY TRANSFER: WASTE SOLIDIFICATION

OBJECTIVE:

1. To promote the use of stabilization/solidification as a final treatment process for the disposal of hazardous wastes.
2. To promote the use of proper laboratory testing methods to evaluate solidified wastes.

RELEVANCE:

The expertise gained at the WTC regarding the mechanisms of contaminant containment and leaching and in the evaluation of solidified wastes must be transferred to ensure optimal use of the technology for the control of hazardous wastes.

WORK PLAN:

1. Organize an International Conference on Solidification in conjunction with ASTM and ORNL.
2. Publish papers to disseminate the findings of the fundamental study completed on the mechanisms of containment and leaching and to promote the use of the Assessment Protocol.
3. Respond to request from users of the technology.

STATUS REPORT - APRIL 1986 TO MARCH 1987

The International Symposium on Solidification will be held in Atlanta from May 3 to 6, 1987 and will bring together experts from the hazardous and nuclear waste field. Some seventy papers will be presented.

A paper entitled "Long Term Leaching Scenarios for Cement-Based Waste Forms", by P.L. Côté and T.R. Bridle was published in Waste Management and Research.

A paper entitled "Long Term Laboratory Evaluation of Cement-based Waste Forms using a Dynamic Leach Test" by P.L. Côté, T.W. Constable and A. Moreira was accepted for publication in the Journal Chemical and Nuclear Waste Management.

Copies of the final report entitled "Contaminant Leaching from Cement-based Waste Forms under Acidic Condition" were distributed to 15 organizations and individuals.

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Pierre Côté prepared a book review of "Hazardous Waste Management Handbook" for the Journal Waste Management & Research.

Pierre Côté presented a paper entitled "The Use of Stabilization/ Solidification for the Containment of Toxic Contaminants" at the Joint APCA/PCAO Conference in Hamilton, April 28.

T.R. Bridle made a presentation on solidification technology to the ON-SITE Training Seminar on July 23.

T.R. Bridle made a presentation at the EPA hearing in Washington, July 14, 1986 regarding the "proposed rule to expand the toxicity characteristic and to replace the Extraction Procedure with the Toxicity Characteristic Leaching Procedure". He presented the approach currently proposed by Environment Canada to assess waste leachability. A copy of the written comments was submitted at the hearing.

P. Côté presented paper entitled "Stabilization/Solidification Processes" at the Canada/US Niagara River Toxics Conference in Toronto on February 4.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR. P.L. Côté

PROJECT NO. 99845

TEL: 336-4605

ACTIVITY NO: 2400

TITLE: ASSESSMENT OF SOLIDIFICATION TECHNOLOGY

OBJECTIVE:

1. To evaluate the applicability of existing processes to new waste streams and to assess new solidification processes from a mechanistic point of view.
2. To use a modelling approach to predict leaching of solidified wastes in a field environment.

RELEVANCE:

Solidification is a relatively new technology; mechanistic studies are still needed to assess its applicability. Furthermore, modelling can be used to extrapolate the results of mechanistic studies in order to predict long term leachability.

WORK PLAN:

Develop joint projects with users of the technology (e.g., OWMC).

STATUS REPORT - APRIL 1986 TO MARCH 1987

OWMC Study

A study entitled "Assessment of Solidification Technologies for the Immobilization of Trace Organic Contaminant" was conducted for the OWMC. The study consisted in determining the leachability of twenty (20) target organic contaminants from five (5) generic solidification processes involving the addition of cement, fly ash, soluble silicates, bentonite and activated carbon. The final project report is in preparation.

Oily Sludge Wastes Solidified with Asphaltic Mixes

An experimental program, to assess the environmental impact of incorporating heavy oily sludges into asphaltic mixes was developed by WTC-WNR staff. The leaching component of the experimental program was completed in mid-February. Results from the toxicological tests conducted with the leachates at the C&P laboratories in Longueuil, Quebec, were received in late February. The freeze/thaw and wet/dry tests are tentatively scheduled to finish in the second week in April and the report should follow by the end of April.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: M.D. Webber

PROJECT NO. 99846

TEL: 336-4519

ACTIVITY NO: 2200

TITLE: TECHNOLOGY TRANSFER: RESIDUE UTILIZATION

OBJECTIVE:

To maximize technology transfer in the field of sludge utilization.

RELEVANCE:

During the past several years extensive laboratory and field studies have been conducted to define optimal sludge treatment and utilization options. Much of this information is not extensively used due to the lack of suitable technology transfer mechanisms. Since major cost reductions are likely to be achieved by implementing the technology, formats for the dissemination of this information must be established.

WORK PLAN:

1. Continue participation in the Commission of European Communities, Treatment and Use of Sewage Sludge Program. Participation during 1985-86 will include a meeting of Working Group 5. Locations and dates to be decided.
2. Continue participation in the Technical Advisory Committee - City of Winnipeg Sludge Disposal. The purpose of this Committee is to advise concerning best practicable sludge handling and utilization/disposal options (Webber and Campbell).
3. Promote the transfer of best practicable sludge utilization/disposal technology by cooperating with Provincial and Regional authorities to sponsor field demonstrations and meetings.
4. Provide technical assistance to the Industrial Programs Branch, to develop a national sludge data base and provide input for decommissioning guidelines.
5. Serve as Environment Canada representative on the Agriculture Canada - Expert Committee on Soil and Water Management.
6. Serve as Environment Canada representative on the Ontario Soil Management Research Committee and on its Waste Utilization & Environmental Quality Subcommittees.

STATUS REPORT - APRIL 1986 TO MARCH 1987

A manuscript entitled "Future developments in sludge disposal strategies" which was presented to an EEC Working Group 5 seminar has been published in Factors Influencing Sludge Utilization Practices in Europe, Davis et al. Eds., Elsvier Applied Science Publishers, 1986, pp 103-144.

A manuscript entitled "The potential for agricultural use of waste iron oxides was presented to a seminar sponsored by the Canadian Steel Environmental Association and has been accepted for publication in Environmental Technology Letters.

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A manuscript entitled "Heavy metal concentrations in Halton Region soils: An assessment for future municipal sludge utilization" has been submitted for publication in the Canadian Journal of Soil Science.

A manuscript entitled "Organic contaminants in Canadian municipal sludges" has been prepared and is undergoing internal review prior to submission for publication in the Canadian Journal of Soil Science.

WTC contributed to a "Position paper on agronomic management of manure" which was published by Agriculture Canada.

Twenty-minute audio-visuals entitled "Land Application Of Treated Municipal Effluent" and "Land Application Of Treated Municipal sludge" and an executive summary of the "Manual For Land Application Of Treated Municipal Wastewater Sludge" have been completed and will be distributed early in fiscal year 1987-88.

Plans have been initiated for a national "Workshop On Sludge Use In Agriculture" to be held in the autumn of 1988. The format will be similar to the one held two years ago in Winnipeg.

WTC are providing technical input to the MISA program, the Industrial Site Decommissioning Steering Committee and are participating in discussions aimed at initiating research into soil-plant relationships on sites that have been heavily contaminated with heavy metals and organic compounds resulting from industrial activity.

The Tricil/ORF contract "Development of a Process for Oil Recovery from Waste Oil Sludges" is progressing on schedule. A Phase I report on waste characterization and process selection is available from the WTC. Ten different recovery processes were assessed and experimental data developed for the six most promising processes. A solvent extraction based process is to be piloted in the final phase of this study.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: T.L. Bulman

PROJECT NO. 99847

TEL: 336-4664

ACTIVITY NO: 2300

TITLE: LAND APPLICATION OF INDUSTRIAL WASTES

OBJECTIVE:

1. To determine the fate and degradability of target organic constituents in industrial waste when applied to soil.
2. To assess the potential of land application for treatment of industrial wastes.

RELEVANCE:

Application of solid waste to land is a method of disposal that has been investigated by a number of industries and is routinely practiced by the oil refining industry. Current US EPA studies indicate that land application is a viable waste treatment alternative, however effects on air and water quality must be investigated for a variety of industrial wastes. A data base for evaluating the suitability of land application for a variety of Canadian industrial wastes is required to assist Canadian managers in developing land application guidelines. This work will also support field studies of land treatment of heavy oil production wastes performed by Western and Northern Region in Saskatchewan and modelling studies of the fate of organic chemicals in soil performed by US EPA.

WORK PLAN:

1. Incubation studies using mixtures of heavy oil production wastes and soil to identify rates of degradation for HNC and PAH constituents.
2. Detailed laboratory assessment of solid/liquid/vapour phase partitioning of ^{14}C labelled HNC's and PAH's in heavy oil waste applied to soil and assess toxicity of leachate.
3. Microcosm studies to assess leaching, volatilization, degradation and plant uptake of ^{14}C-HNC's and PAH's in heavy oil waste applied to soil and assess toxicity of leachate.
4. Analysis of field samples for PAH's and HNC's in support of W&N Region study.
5. Provide technical advice and project review for PERD supported research.
6. Participate in US EPA project review meetings to exchange technical expertise.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Sampling of the refinery waste fingerprint study for PACE continued. Extraction and cleanup of samples was carried out by WTC and analysis of extracts was performed by Zenon Environmental.

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Work was begun on the PACE Report for the refinery waste study. An interim draft report was distributed to the PACE committee members and discussed at a progress review meeting at WTC, June 25. A meeting was held on 20 Jan. with D. Hagopian of PACE to discuss progress of the report and current studies of mutual PACE and WTC interest. Preparation of the final report for PACE is continuing.

Experimental work was completed for the microcosms using refinery soil. Leaching of naphthalene was observed (3% of ^{14}C added) to a depth of 6 inches with elution of two pore volumes of water. No translocation of ^{14}C labelled organics from soil to plant shoots was observed. K. Hosler presented results in a paper "Microcosm for Assessing the Fate of Organic Chemicals in Soil" by K.R. Hosler and T.L. Bulman at the CAWPRC Symposium, CCIW, April 30, 1986. T. Bulman and K. Hosler also presented the results at a poster session at the Technology Transfer Conference in Toronto, 8 - 9 Dec.

Work was continued on the heavy oil study for PERD. A composite oily sludge was prepared for use in the WTC and Agriculture Canada laboratory studies. The waste was extracted and fraction on a neutral alumina column. Chemical analysis and toxicity testing was performed on the individual fractions and revealed that the fraction containing PAH's, substituted PAH's and heterocyclic sulphur compounds exhibits most toxicity. Some toxicity was also observed with the fraction which should contain HNC's, however no HNC's were identified. The focus of the experimental program will therefore include PAH and PASH as well as selected HNC's.

Microcosms for the study of PAH and HNC in heavy oil waste were fabricated. K. Hosler travelled to the Maidstone, Saskatchewan site, May 27-29, to supervise the collection of nine undisturbed soil cores for use in the heavy oil study. Heavy oil (EOR) waste was applied to the field site in early June and a subsample was sent to WTC for addition to the soil cores in microcosms. Samples of heavy oil waste from EOR and conventional processes were provided to Tricil for a study of oil recovery.

Another nine microcosms for the study with heavy oil waste were packed with Mississippi soil. Saturated hydraulic conductivity and integrity of all eighteen of the new microcosm soil columns were tested by obtaining breakthrough curves with KBr solution and a constant head apparatus. Further work on the microcosms study was delayed as ^{14}C-labelled organic chemicals have not been received. The soil moisture extraction equipment was set up and work will begin on defining moisture retention curves for the oil treated soils.

A fingerprint study was set up with additions of 5 HNC's (pyridine, quinoline, indole, carbazole, acridine) and chrysene as pure chemicals to soil at concentrations of 0, 1, 5, 10, 100 mg/kg. Measurement of soil respiration identified that all levels of chemical addition were not detrimental to microbial activity. Following two months incubation, soil

and aqueous extracts of soil were submitted for chemical analysis and the extracts were submitted for toxicity testing. Soil analysis provided preliminary loss rates of the chemicals from soil. Analysis for pyridine, however, has been unsuccessful using GC/FID and GC/ion trap. None of the chemicals were found in the aqueous extract. The levels of toxicity and mutagenicity determined with aqueous extracts did not differ from background levels in Microtox, algae and SOS Chromo tests.

T. Bulman attended a review meeting of the EPA Land Treatability Study Group in Oklahoma City, April 8 - 11. The possibility of WTC participating in a field study for verification of the EPA RITZ model was discussed. Plans were made to incorporate the evaluation of EPA's RITZ model into a decommissioning study to be performed by Monenco. A proposal was developed to request funding from US EPA through an interagency agreement for field evaluation of the RITZ model as part of the decommissioning study program. Budget and design of field and laboratory experiments for the decommissioning study were discussed with Martyn Riddle of Monenco. Soil and sludge was collected from the Nanticoke site for use by WTC, Utah State and EPA. Preliminary bulk density and hydraulic conductivity tests were performed.

Meetings were held with Ron Cameron from the Texaco refinery at Nanticoke, John Matthews of US EPA, Ron Sims of Utah State University and Martyn Riddle of Monenco at Nanticoke, 21 Oct., and with members of the Industrial Site Decommissioning Steering Committee in Toronto, 22 Oct., to review the Monenco proposal. A meeting was held 10 March with the Technical Working Group and 11 March with the Steering Committee to finalize plans for the project now entitled Development of Methods for Establishing Site-specific Cleanup Criteria for Industrial Site Decommissioning.

T. Bulman and R. Scroggins (IPB) met with CPA and Norwest Soil Research representatives in Calgary, 7 May, to discuss the field program of the PERD study Land Treatment of Deisel Invert Mud study.

T. Bulman attended the Symposium on In Situ Treatment of Hazardous Waste at Knoxville, Tennessee, June 9 - 10 and visited the Oak Ridge National Lab., Oak Ridge, Tennessee, June 11, to discuss progress on the land treatability study with Barbara Walton and explore other areas of mutual interest for ORNL and WTC.

T. Bulman attended the XIII Congress of the International Society of Soil Science in Hamburg, West Germany, 12 - 21 Aug. and presented a poster session "Canadian Research on the Use of Soil for Treatment of Petroleum Wastes". T. Bulman also met with J.F. de Kreuk of TNO in Delft, the Netherlands 18 Aug. to discuss research on oily waste degradation in soil and possibilities for cooperative work.

T. Bulman attended a meeting of OSMRC Waste Utilization subcommittee in Guelph, 3 March.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: T.W. Constable

PROJECT NO. 99848

TEL: 336-4716

ACTIVITY NO: 2300

TITLE: NITEP: SOLID WASTE MANAGEMENT

OBJECTIVE:

To provide technical assistance and support with respect to programs aimed at demonstrating resource recovery and conservation from solid wastes.

RELEVANCE:

Residues generated by both the municipal and industrial sectors are often not considered as potential candidates for resource recovery. Increasing public concern with respect to residual deposition and ever increasing energy costs are exerting more pressure on the technological community to engineer resource recovery systems. Incineration of garbage for energy recovery is gaining acceptance by the public, but the environmental implications of this technology are not fully defined.

WORK PLAN:

1. Provide support to the National Incineration Testing and Evaluation Program (NITEP) by:
   (a) conducting leaching tests on the NITEP solids wastes generated;
   (b) assessing technologies for the immobilization of inorganic contaminants in these residues;
   (c) providing general input to the NITEP program.
2. Support U/P's and other proposals that address resource recovery.

STATUS REPORT - APRIL 1986 TO MARCH 1987

NITEP Phase IIA

The experimental program for Phase IIA on the Quebec City FLAKT ashes was completed in April of 1986. The final report for this phase of the study, "Assessment of Ash Contaminant Leachability" was completed in the fall of 1986 and released under EC's manuscript series in December.

S. Sawell presented the paper "Assessment of Heavy Metal Leachability from Municipal Solid Waste Incinerator Ashes" at the 22nd Canadian Symposium on Water Pollution Research in Toronto, Feb. 19. The paper is currently being reviewed for final approval before being submitted to Waste Management and Research for publication.

The paper "Leachability Estimates for Organic and Inorganic Contaminants in Ashes from Lime-based Air Pollution Control Devices on a Municipal Waste Incinerator" has been tentatively approved for presentation at the Air Pollution Control Association's annual conference in New York City, June 21-26. The paper will be published in the conference proceedings.

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Phase IIB

The experimental program for Phase IIB of the NITEP study (mass-burn facility in Quebec City) was developed by WTC-IPB staff during meetings in July and August. Long range plans were developed to include the evaluation of solidified/stabilized ashes as well as examining the feasibility of metal recovery and vitrification processes in the next fiscal year.

S. Sawell attended a meeting in Toronto in September to discuss QA/QC protocols for Phase IIB ash analyses. IPB, Environment Quebec, Ontario Ministry of the Environment and contract laboratories were also represented at the meeting.

Phase IIB ash samples were received in August and September. Laboratory testing began immediately and the experimental program was completed in January. Almost all of the analytical results for the metals have been received and processed. Organic contaminant analyses from RRETC are expected to arrive in early April. A draft of the final report on ash leachability for Phase IIB should be ready in late May.

Future Programs

T. Bridle attended the EPA/EC Municipal Waste Combustion Workshop at Research Triangle Park in North Carolina, Dec. 9-11. This workshop laid the foundation for the formation of a working group on management strategies for MWC ashes. T. Bridle and S. Sawell attended a meeting in Boston, Mass., March 30-31, to discuss the development of an international data base for incinerator ash management. The meeting's goals were to share technical information, as well as develop co-operative efforts in researching ash management strategies. Further ash characterization studies, as well as solidification, metal recovery and possibly vitrification process feasibility studies are slated to begin early in the FY 87-88.

SECTION:RESIDUE MANAGEMENT

PROJECT MGR: H.W. Campbell

PROJECT NO. 99850

TEL: 336-4720

ACTIVITY NO: 2300

TITLE: DEMONSTRATION OF SLUDGE CONVERSION TECHNOLOGY

OBJECTIVE:

To oversee the design, construction and operation of a 1 tonne/day demonstration conversion reactor system in support of the commercialization of the technology.

RELEVANCE:

Canada produces about 500,000 tons of sewage sludge annually, which is disposed of at a cost of approximately $105 million. Recent research has indicated that sewage sludges can be thermally converted to synthetic oil and char. The first phase of this study has demonstrated that Canadian sludges are amenable to processing. If the feasibility of this process can be demonstrated in Canada, the economic benefit would be about $140 million with the production of roughly 1 million barrels of oil annually.

WORK PLAN:

The contract to Petro Sun International Incorporated, to design, construct and operate a 1 tonne/day pilot conversion reactor system will provide the required data to permit commercialization of the technology. The plant is scheduled to be constructed by Sept. 1986 and operated till Oct. 1987.

STATUS REPORT - APRIL 1986 TO MARCH 1987

The one tonne per day pilot plant conversion system was fabricated in Montreal by Petro Sun International and delivered to the Woodward Ave. sewage treatment plant in September 1986. The Hamilton-Wentworth Regional Municipality provided a site for the pilot plant in the standby power building. Installation and debugging of the system continued through February 87. The Minister of the Environment officially opened the pilot plant on January 22, 1987.

Preliminary runs confirmed that the pilot plant generally operated as expected. The sludge was conveyed through the reactor without any apparent difficulty. The char produced was dry, free flowing, completely free of any visible signs of oil and only warm to the touch. The oil had the same general characteristics as that generated by the bench-scale reactor. The condenser and decanter combination were effective in accomplishing the liquid-vapour and liquid-liquid separations.

During the course of the startup, a number of modifications were made to both the equipment and the operating procedure. A third heating duct was installed at the downstream end of the reactor in order to bring the reactor up to temperature under design loading. New end plates and seals were installed on the reactor to allow operation at greater than atmospheric pressure. The screw flights on both the feed and char conveyor were modified to improve discharge from their respective hoppers. Several modifications were made to the drive unit on the feed screw in order to achieve the correct combination of capacity and torque. Additional instrumentation such as thermocouples and a char level detector were also added to the system.

One of the primary considerations in locating the pilot plant at the Woodward Ave. plant was the existence of a sludge dryer on site. It was assumed that this would essentially ensure an unlimited supply of dried sludge for the startup and debugging phases. Unfortunately, continuous operation of the dryer at Hamilton has not yet been achieved and alternative sources of dried sludge have been located. Approximately 3 tonnes of sludge from Rockford, Illinois were obtained. Although the sludge had the appearance and odor of raw sludge, the oil yields from the conversion runs were in the range expected with either a digested or highly stabilized sludge. Sludge from a second source, Atlanta, Georgia, was also tested and the results were similar to those expected for a typical mixed raw sludge. Subsequently, 10 tonnes of Atlanta sludge were also obtained. The experimental program will be conducted using the two sludges currently on hand plus Hamilton sludge when it becomes available. The evaluation phase has just been initiated and will continue for approximately six months.

The US patent "Process and Apparatus for the Conversion of Sludges" was issued in October, 1986. Patent applications in Canada, Japan and the European Community are in various stages of development. Petro Sun International are currently negotiating with Canadian Patents and Development Limited for a licence to market the "oil from sludge" technology.

A paper entitled "Oil From Sludge: A Technology Update" was presented at the 9th Canadian Symposium on Wastewater Treatment in Montreal, November, 1986.

Professor Bayer and Dr. Kutubuddin from Tubingen University, West Germany, visited the WTC on November 20 and 21 to review joint technical/commercial progress on the oil from sludge technology, to visit the pilot plant and to discuss future collaboration.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: H.W. Campbell

PROJECT NO. 99851

TEL: 336-4717

ACTIVITY NO: 2300

TITLE: CONVERSION OF RESIDUES TO LIQUID AND SOLID FUELS

OBJECTIVE:

To generate process design information from a lab-scale continuous reactor for a variety of source materials.

RELEVANCE:

Canada produces about 500,000 tons of sewage sludge annually, which is disposed of at a cost of approximately $105 million. Recent research has indicated that sewage sludges can be thermally converted to synthetic oil and char. The first phase of this study demonstrated that Canadian sludges are amenable to processing and a continuous reactor system has been designed and operated to generate preliminary process design information for a one tonne per day pilot plant facility.

WORK PLAN:

1. Expand process design data base with information from additional municipal sludges.
2. Evaluate alternative source materials, e.g., refuse, animal wastes, etc.
3. Conduct experiments to answer specific questions with respect to design of pilot system.
4. Compare operation of bench scale and pilot scale reactors i.e., evaluate scale-up potential.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Process Design

The level of effort expended on the bench-scale reactor was significantly reduced over the past year due to the priority of bringing the pilot scale system online. Sludges from Rockford and Atlanta were tested on the bench scale system to determine their suitability for pilot scale testing. Samples of digested sludge from Hamilton were tested to compare drying techniques. Sludge from the full scale rotary dryer consisted of relatively dense pellets similar in appearance to BB shot. The sludge dried in an oven at the WTC was ground after drying and was therefore much more fluffy in nature. The test results indicated no significant differences between the two sludges in terms of either product yield or quality.

In an attempt to better understand the basic mechanisms involved in the conversion process, a series of runs using Burlington raw sludge and essentially pure lipids and proteins were completed. The objective of these experiments was to investigate the relationships between oil quantity/quality and the relative amounts of lipids or proteins. The lipid source was lauric acid while the protein source was soybean protein isolate. Most runs contained 30% sludge for the provision of the necessary catalysts but tests on pure lipids and proteins were also completed. Material handling problems were experienced with those runs which contained protein at levels of greater than 35%. Oil yield increased generally in proportion to the amount of lipids or proteins added but it was not determined whether the mechanism was conversion or straight distillation. High levels of protein increased the viscosity of the oil significantly but the effects on other oil properties was not obvious.

Universtiy of Toronto Contract

A significant effort was oriented towards developing a standard procedure for predicting oil yield based on some analytical measurement of the sludge in question. Extraction of the sludge using the soxhlet method and chloroform as the solvent showed the most promise. Reproducibility experiments showed that based on twelve samples of Burlington raw sludge, the mean yield was 9.53 wt%, with a standard deviation of 1.00 wt% and 95% confidence interval of +0.63. Analyses conducted on eleven sludges resulted in a range from 6.1% to 28.0%. Although the data base is still small, oil yield appears to be a function of both lipid content (chloroform extract) and protein content ($TKN\text{-}NH_3$). Using two different relationships i.e. one for raw sludge and another for digested sludge, it appears to be possible to predict the oil yield based on these two measurements. Additional data is necessary to confirm the relationship and to establish statistically significant confidence limits.

Carbon-13 NMR analyses was used for quantitative determination of chain lengths and relative quantities of alkanes and carboxylic acids. These analyses showed that oil generated by operating the bench-scale reactor in a counter-current mode had a higher relative quantity of alkanes as compared to oil generated in a co-current mode, from the same sludge. This infers that a better "quality" oil can be obtained by operating the reactor in a counter-current mode.

Preliminary work was also initiated on upgrading the oil from the pilot plant. Acid washing was carried out on one of the first samples of oil produced from the pilot scale reactor.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: H.W. Campbell

PROJECT NO. 99852

TEL: 336-4720

ACTIVITY NO: 2300

TITLE: ENVIRONMENTAL ASSESSMENT OF SLUDGE CONVERSION TECHNOLOGY

OBJECTIVE:

To develop the process/analytical capability to permit assessment of the potential emissions from a sludge conversion plant.

RELEVANCE:

The sludge conversion technology developed at the WTC appears to have considerable commercial potential and may well form the basis for a significant portion of the future sludge management market. The technology is unique and the full potential environmental impact of this technology needs to be assessed.

WORK PLAN:

Under a U/P submitted by Dearborn Environmental, an integrated process/analytical system will be constructed to permit assessment of PAH/HNC emissions from the sludge conversion process. Emissions from the combustion of the synthetic fuel produced will also be assessed.

Act as Scientific Authority on this contract.

STATUS REPORT - APRIL 1986 TO MARCH 1987

During the year the integrated Thermal Data Generation/Multidimensional GC/Ion Trap Detector System was assembled and debugged. The Thermal Data Generation System (TDGS) provides thermal evolution of contaminants from the sample and, if desired, subsequent combustion and high temperature (1200°C) destruction. Evolved gases from the TDGS are routed to a Siemens Multidimensional GC (MDGC) for collection and separation. Compound identification is achieved using the Finnigan Ion Trap Detector (ITD) and quantitation is done using either the flame ionization detector (FID), the ITD or the Nitrogen Specific Detector (NSD).

Significant effort was expended in developing appropriate MDGC methodology for the analysis of selected PAH's and HNC's. A mixture of 16 PAH and 25 HNC standards were used to develop quantitation methodology. Using FID, the PAH's could be quantified down to concentrations as low as 0.18 ng/µL. The ITD could only quantify the PAH's down to concentrations of approximately 1 ng/µL. The original NSD had to be replaced and the new system is capable of quantifying HNC's at concentrations as low as 400 pg/µL.

Deposition of evolved gases on the GC can be accomplished using either the programmable temperature vaporizer (PTV) or a gas sampling valve (GSV). The PTV can be operated cryogenically (-30°C) to ensure complete capture of low molecular weight compounds.

The entire system has been used to quantify HNC's present in SYSCO tar pond sediments. Fifteen individual HNC's were identified and quantified. Total HNC concentration is roughly 230 µg/g, with substituted pyridines and quinolines predominating.

T.R. Bridle made a presentation entitled "Thermal Evolution and MDGC-Ion Trap Detection of Organic Contaminants in Residues" at the 25th Annual Eastern Analytical Symposium in New York City, October 23, 1986.

The system is now ready for use to assess the environmental impact of combusting fuels generated from the oil from sludge process.

SECTION: RESIDUE MANAGEMENT PROJECT MGR: H.W. Campbell

PROJECT NO. 99853 TEL: 336-4717

ACTIVITY NO: 2300

TITLE: ASSESSMENT OF INTEGRATED SLUDGE MANAGEMENT SYSTEMS

OBJECTIVE:

To develop a methodology to define cost effective integrated sludge management options.

RELEVANCE:

Sludge management schemes which incorporate incineration as a unit process are becoming increasingly popular in large urban centres. Incineration is a relatively expensive option (unit costs estimated at $200 to $400 per dry tonne) and efforts are being made to modify the systems such that they represent cost effective integrated sludge management schemes. Currently in Southern Ontario, four different approaches are in operation but it is not possible to compare costs on a common basis. A methodology which would define the boundary conditions and develop accurate cost estimates would be a valuable aid in determining the most cost effective sludge management system.

WORK PLAN:

1. The work will be carried out by Proctor and Redfern under an Unsolicited Proposal.
2. To provide technical support as Scientific Authority to this contract.

STATUS REPORT - APRIL 1986 TO MARCH 1987

Capital costs were obtained for all four plants and were converted to a common time base of December 31, 1985. Decisions were made as to what costs should be included as sludge costs, and it was decided to delete redundant capital items such as the vacuum filters at Hamilton.

Operating budgets for 1986 were obtained for each plant and analysed to ensure that for any given cost item, the same components were present for all plants. The actual operating and maintenance expenditures for 1986, for each plant, are currently being analysed.

At a meeting of the Steering Committee in early February, it was agreed that the data would be presented in the following four ways:

1. $/tonne of raw sludge processed based on the actual facilities that exist and the actual 1986 O&M costs.

2. $/tonne if sludge volumes were increased to design capacity (usually dictated by incinerator capacity).

3. $/tonne at "design" capacity without any standby equipment capacity.

4. $/tonne at "design" capacity with consistent specified standby capacity.

The final report is expected to be available by early summer 1987.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: T.L. Bulman

PROJECT NO. 99854

TEL: 336-4664

ACTIVITY NO: 2400

TITLE: DEGRADATION OF CHLORINATED ORGANICS IN SOILS SYSTEM

OBJECTIVE:

1. To determine if biological degradation can be appropriately managed to decontaminate soil containing chlorinated organic compounds.
2. To assess the potential of land application for treatment of chlorinated wastes.

RELEVANCE:

Substantial quantities of soil contaminated with chlorinated organic compounds, including PCB's, are currently awaiting a suitable method for cleanup and disposal. Given the volume of soil involved, the potential for spillage during extensive transportation to incinerator facilities and the high cost of incinerating soil with a relatively low content of ignitable material, it is appropriate to explore alternative methods of treatment for contaminated soil. Microbial degradation by native soil organisms or selected PCB degrading strains in a controlled and contained incubation system may provide a cost effective solution which can be implemented on a contaminated site. Information on the fate and degradation of chlorinated hydrocarbons also can be extended to assess the feasibility of treating chlorinated wastes (for example wood treatment wastes) by land application.

WORK PLAN:

1. Completion of a biometer flask study demonstrating the degradation of ^{14}C labelled hexachlorobiphenyl in soil with acclimated soil microorganisms and chemical analogs.
2. Assessment of 5 alternative chemical analogs and 5 microbial innoculants as enhancers of ^{14}C labelled, highly chlorinated PCB's in soil.
3. Laboratory incubation study assessing degradation and transformation of PCB isomers in an Aroclor 1254 mixture added to soil, including toxicity testing of soil extracts.

STATUS REPORT - APRIL 1986 TO MARCH 1987

A contract was initiated April 1 with Dearborn Env. for development of methods to enhance PCB degradation in soil and assessment of toxicity. A meeting was held April 17 to establish task details, performance indicators and outputs for the first six months. Dearborn staff completed a literature review of methods for PCB analysis and a review of toxicity testing procedures is in progress. The GC for PCB analysis was received in June and methods development was initiated. The HPLC and on-line ^{14}C detector was delivered and methods development for ^{14}C labelled PCB and

products was also initiated. Federal Pioneer and Saskatchewan Environment agreed to provide financial support for this study.

T. Bridle and T. Bulman met in Regina, 27 May, with representatives of Federal Pioneer, Saskatchewan Environment, Ground Engineering and Univ. of Saskatchewan Dept. of Civil Engineering. The project work plan was presented and the possibility of funding for FY 87/88 was discussed.

T. Bulman attended the Bioqual Workshop at CCIW, 21-22 May and discussed with A. Chakrabarty the possibility of obtaining specialized PCB degrading microorganisms.

Cultures of PCB degrading white rot fungi (Phanaerochete chrysosporium) and a bacterium were obtained from NRC Biotechnology Research Institute and General Electric, respectively. Contaminated soil from the Federal Pioneer site was analysed for PCB content and assessed for microbial activity.

Shipment of the detector for GC analysis was delayed, resulting in delays in method development. Additional delays occurred due to breakdown of the autosampler and breakage of injection needles. Apparatus was purchased for measurement of carbonate and low molecular weight fatty acids by differential refractometry.

Dearborn staff initiated the first series of incubations. Sources of microorganisms were tested in enrichment cultures with soil, a suite of PCB's, biphenyl and lignin (straw). The cultures were incubated aerobically at 20°C as slurries on shakers. The concentration of PCB's were monitored to assess PCB degradation. This trial demonstrated substantial growth of specialized bacteria on Araclor 1254 and biphenyl as sole carbon source. Analytical results indicated 25% degradation of tetra-, penta- and hexachlorobiphenyl isomers in a 89 day period with specialized cultures of bacteria.

A project review meeting was held 1 Oct. with T.Bulman, T.Bridle and Dearborn staff.

S. Camilleri presented a paper entitled "The Effect of Soil Amendments on the Fate of ^{14}C-3,4,5,3',4',5'-hexachlorobiphenyl" at the Annual Meeting of the American Society of Agronomy, in New Orleans, 30 Nov. - 5 Dec.

Additional soil was received from Federal Pioneer and was prepared for use in the subsequent fate studies. Studies were also performed to assess the effectiveness of various biosurfactants on increasing the desorption PCB from Federal Pioneer soil. Two of the surfactants appear promising.

SECTION:: RESIDUE MANAGEMENT PROJECT MGR: H.W. Campbell

PROJECT NO. 99855 TEL: 336-4717

ACTIVITY NO: 2200

TITLE: TECHNOLOGY TRANSFER: RESIDUE TREATMENT

OBJECTIVE:

To maximize technology transfer in the field of sludge/residue treatment.

RELEVANCE:

In the past few years, major advances have been made in the development of new technology for sludge/residue treatment and the design of integrated sludge management systems. Much of this information is under utilized due to the lack of suitable transfer mechanisms between researchers and users. Improved technology transfer can result in significant economic benefits to municipalities or industries.

WORK PLAN:

1. Continue participation in the Commission of European Community Treatment and Use of Sewage Sludge Program. Participation during 1986/87 will include a meeting of Working Party 1, Sludge Processing, but the date and place have not been determined as yet.
2. Provide technical assistance to the Industrial Programs Branch, to develop, evaluate and/or promote new cost-effective sludge/residue treatment technology.
3. Actively promote the transfer of state-of-the-art residue treatment technology by participation at seminars, conferences and meetings of municipal officials or public citizens.

STATUS REPORT - APRIL 1986 TO MARCH 1987

A report from PAPRICAN on tests conducted on a dewatering device at Revere Copper and Brass at Rome, N.Y. was reviewed by personnel from EM&R, IPB,WTC and a private consultant. It was agreed that the conclusions in the report were supported by the data generated by PAPRICAN and by the earlier contract with IEC/Beak. It was decided that there was not enough concrete evidence of the potential benefit of this technology to the pulp and paper industry, to warrant committing any additional resources.

H. Campbell visited a filter press installation in Saarbrucken, West Germany in November 1986. The press demonstrates a new concept in filter press technology in that it generates very high pressures (up to 15 atm) and operates in a continuous mode. He also spent a day at the Water Research Centre (WRC) in Stevenage and a day at the Thames Water Authority in London. As a result of this visit, the WRC and the WTC will cooperate

in a study next year incorporating WTC's sludge conditioning controller and WRC's Optifloc mixer to determine the impact of mixing on the polymer requirements of a belt filter press. The Thames Water Authority are very interested in participating in a demonstration of the sludge conditioning controller.

SECTION: RESIDUE MANAGEMENT

PROJECT MGR: T.W. Constable

PROJECT NO. 99856

TEL: 336-4716

ACTIVITY NO: 2400

TITLE: STATE ESTIMATION OF LANDFILL LEACHING

OBJECTIVE:

Develop a computer model to predict leachate characteristics in a landfill, using state estimation (i.e., Kalman filtering) techniques.

RELEVANCE:

Leachates from waste disposal sites contain a variety of toxic constituents which can contaminate groundwater systems. Several mathematical models have been proposed to predict the quality and quantity of these leachates, however none of the models developed to date have used state estimation techniques which would allow probability distributions to be assigned to the predicted variables. The use of these techniques would also allow information available in the literature and obtained from leaching tests to be used for the development of "a priori" probability distributions for input variables.

WORK PLAN:

1. Conduct a literature review on models that have been developed for the simulation of leaching in landfills (June 1986).
2. Use or modify these models to formulate a deterministic process model which will simulate water flow through a landfill and interactions between the leaching medium and waste.
3. Formulate the measurement model (i.e., assign values and variance estimates to the input variables) based on literature values and the results of leaching tests.
4. Write a Fortran program to solve the Kalman filter equations for the process and measurement models.
5. Test the program using field data.

STATUS REPORT - APRIL 1986 TO MARCH 1987

During April to December, two University of Waterloo Co-op students, Bonita Gionet and Don Sandys-Wunsch, assisted in the development of two computer models that attempted to simulate waste leaching using Kalman Filter state estimation techniques.

The first model simulated leaching from a solidified waste. The program was tested using the results of a dynamic leaching test conducted on a cement-based waste form, but insufficient data was available to allow the program to produce filtered estimates of many of the state variables. In order to use the program effectively, Sequential Chemical Extraction

analyses would have to be conducted on the leached residues at various stages in the dynamic leaching test.

Work was then started on the development of a Kalman Filter program to simulate waste leaching in landfills using a model developed by Straub and Lynch (ASCE Journal of the Environmental Engineering Division, April, 1982). The state vector and state transition matrix were developed using several vertically cascaded well-mixed reactors (i.e., cells) to represent the landfill. However, problems were encountered due to the lack of measurement data, the need for very large and unwieldy matrices to represent the state variable propogation equations, and the inability of the program to use time increments greater than one or two days, necessitating very long computational times. This project has been cancelled indeterminately because of these problems, the need for a much more powerful PC to handle the data arrays and matrix manipulations, and the unavailability of technical support staff with knowledge in Kalman Filtering techniques.

PROJECT STATUS REPORTS - PHYSICAL/CHEMICAL PROCESSES SECTION

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: A. Zaidi

PROJECT NO. 99972 TEL: 336-4618

ACTIVITY NO: 2400

TITLE: SPECIFIC CONTAMINANTS REMOVAL TECHNOLOGY FOR INDUSTRIAL EFFLUENTS

OBJECTIVE:

To ensure the availability of appropriate technology for removing specific contaminants of concern from industrial effluents with emphasis in 1986/87 on the organic chemical industry.

RELEVANCE:

The control of toxic organic chemical wastes is a departmental priority issue. The proposed work will assist in developing cost-effective, at-source control of toxic organic chemicals from industrial plants.

WORK PLAN:

1) In 1985/86, bench scale studies were completed on the use of activated carbon for recycling CCl_4 present in wastewaters from an organic chemical plant. Focus in 1986/87 will be on publishing the results of the study (by Sept. 30, 1986) and on developing a joint industry-government program for field demonstration of the process (with the construction and installation of a system completed by March 31, 1987).
2) Provide technical assistance/advice, as required to C&P-IPB and regional personnel, industry and other concerned agencies.
3) Maintain knowledge of the latest developments in toxics removal by adsorption, and develop improved techniques for evaluating the adsorption process on bench and pilot scale.

STATUS REPORT - APRIL 1986 TO MARCH 1987

General

Activities under this project involved preparation of a report on full scale carbon systems operating at wood preservation plants, negotiations with a chemical manufacturing plant to arrange for pilot field demonstration of carbon tetrachloride recovery from wastewater by activated carbon, and the development of methodologies and a data base for evaluating activated carbon adsorption technology for specific toxics removal from wastewaters. Advice and assistance was provided to the Regions and Headquarters as required.

Performance of Full Scale Carbon Columns

Project field work was conducted in 1985. It involved the evaluation of the performance of two full scale activated carbon systems treating wastewater from wood preservation facilities. A draft report on the work

was completed and forwarded to the plant personnel for review. This review resulted in a number of concerns which were discussed with plant officials. The draft report is now being finalized and is expected to be available during the next fiscal year.

Recovery of Carbon Tetrachloride

Earlier bench scale work had indicated the feasibility of using activated carbon for the recovery of carbon tetrachloride from a waste stream at a chemical manufacturing plant in Ontario. The WTC staff met with the plant personnel to explore the possibility of jointly sponsoring/conducting a pilot plant study to evaluate the concept under actual field conditions. Negotiations are continuing to reach an agreement on the arrangements for such a study.

Additional bench-scale tests were conducted this year to (1) evaluate alternatives for the pretreatment of the waste stream for removing suspended particulate, and (2) compare the effectiveness of three carbons for the recovery of carbon tetrachloride from the waste stream. Of the alternatives (microfiltration, coagulation/settling, and pH adjustment with direct filtration) evaluated for pretreatment, pH adjustment with direct filtration through a 0.5 micron cartridge filter was found to be most cost-effective. Of the three activated carbons (Calgon F400, Calgon PBL and Norit Super Row 0.8) evaluated during the tests, Norit Super Row 0.8 was found to be significantly more cost-effective. At year end, in-plant bench-scale tests were continuing to confirm the effectiveness of the selected pretreatment process in conjunction with adsorption of CCl_4 on Norit carbon.

Data Base on Adsorption of Specific Organics

Work was started on developing a data base on the equilibrium adsorption capacity and kinetics of adsorption of specific toxic organics on activated carbon. It is expected that the published data and several mathematical models (with different levels of sophistication) will be organised in the data base in such a manner which will allow the practicing engineer to design or evaluate activated carbon systems for specific applications. Complementary to the development of the data base is the on going work on the generation of adsorption data on specific toxics where such data are not availiable in the literature (or if the published data are considered to be inadequate). This is a long-term, lower priority activity being conducted with the help of summer students as feasible.

Technical Advice

Advice and assistance was provided to the C&P Ontario regional office in their review of the carbon system evaluation program developed by Dow Chemical for the Scott Road Landfill leachate treatment system. A QA/QC program was developed and field sampling was carried out to assist Dow, MOE and C&P Ontario Region in evaluating the effectiveness of the proposed study by Dow.

SECTION: PHYSICAL/CHEMICAL PROCESSES

PROJECT MGR: D. Averill

PROJECT NO: 99975

TEL: 336-4747

ACTIVITY NO: 2400

TITLE: PROCESS CONTROL AND UPGRADING OF EFFLUENT FILTRATION OPERATIONS

OBJECTIVE:

(1) To develop process control and monitoring strategies for granular media filters employed in either municipal or industrial wastewater treatment processes.
(2) To develop a better understanding of filter design and operation procedures to refine the design of filtration systems.
(3) To optimize granular media filter systems for specific applications, including the treatment of: municipal primary effluent, municipal secondary effluents (including enhanced phosphorus and trace contaminants removal), combined sewer overflows, and various industrial wastewaters, (e.g. Stanleigh radium-226 removal plant, produced water treatment).

RELEVANCE:

Granular media filtration is a solid/liquid separation operation used in the treatment of municipal and industrial wastewaters, the treatment of potable water, and in many industrial processes. Optimization of the many design and operational variables is a time-consuming task involving empirical procedures. Automatic control and data acquisition systems are essential to the improvement of design and operation methods. These systems will also improve mathematical modelling capabilities which will provide a better understanding of filtration mechanisms. The end product will be more efficient methods of designing and operating filters for specific tasks such as the removal of fine metallic precipitates from industrial effluents.

WORK PLAN:

A filtration pilot plant, with computer control and monitoring facilities, has been built and tested using municipal wastewater. The automated systems and the empirical optimization techniques developed in the early stages of this study were successfully transferred to Project 82 (PERD) in FY 1984/85. In FY 1985/86 preliminary tests were conducted with an on-line particle analysis system; interfacing this state-of-the-art instrument with the pilot plant and process control computer caused delays in the project. (1) In FY 86/87 mathematical modelling and optimization work will be undertaken leading towards a design model (completion FY 87/88). (2) Technical assistance/advice will be provided to C&P-OR personnel concerned with the operation of the Stanleigh Mine effluent Ra-226 removal facility (Filtration plant).

STATUS REPORT - APRIL 1986 TO MARCH 1987

Pilot Scale Filtration Design Activities

Installation of the on-line particle size analysis system was completed in the first quarter of the fiscal year. Data management programs were written to combine the particle size and headloss data in a form suitable for subsequent use in modelling. Shake-down tests were conducted; the resulting data were compared to predictions obtained from existing models, and were used in preliminary model fitting tests. Anomalous data obtained from the particle size analysis system resulted in erroneous estimates of specific deposit, a key parameter in filtration models. The results of the preliminary model fitting tests consequently led to further examination of both the hardware and software used to produce the particle size data.

All aspects of the particle size analysis system were reviewed. The principal objective was to identify and eliminate large errors which may have resulted from factors such as incorrect dilution, retainment and sloughing of particles within the sampling/dilution system, air bubbles in the sensors, errors in data management, etcetera. Hardware and software modifications were undertaken and subsequent tests demonstrated improved performance. Results from the modified sampling system provided a semi-quantitative picture of filter behaviour. Particles of different size and surface properties were shown to have different deposition patterns. Particle agglomeration was shown to occur within the filter. However, mass/volume correlations indicated that there were still sampling problems to be addressed.

Further tests and modifications were undertaken to ensure that samples of the suspension were being correctly extracted from the filter, transported, diluted and analyzed. In addition, the data management programs were revised to accommodate longer runs and to provide greater flexibility for graphing and modelling. By the end of March, 1987, the apparatus was producing data which were free of obvious errors, and much of the work was redirected to the task of using the multi-dimensional data array for process modelling.

Stanleigh Mine, Elliot Lake, Ontario

Consultation with Rio Algom and Ontario Region was continued this fiscal year. It appears that the radium removal system consisting of precipitation of the radium as barium radium sulphate followed by granular media filtration is now operating close to the performance objectives.

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: D. Vachon

PROJECT NO: 99977 TEL: 336-4558

ACTIVITY NO: 2400

TITLE: TREATMENT OF "WOODROOM AND PAPERMAKING" EFFLUENTS IN THE PULP AND PAPER INDUSTRY

OBJECTIVE:

To provide technical assistance to HQ and Regional personnel concerned with pulp and paper wastewater treatment systems. To develop and demonstrate at bench scale, treatment strategies for the treatment of "woodroom and paper making" effluents and to demonstrate the technology at full scale.

RELEVANCE:

Problems have been identified with the operation of clarifiers used for treating "wet barker" effluents and newsprint mill effluents at a number of pulp and paper mills across Canada. As these effluents contain suspended material of colloidal size and toxic "resin acids", satisfactory treatment system performance is essential.

WORK PLAN:

(1) In 1983, on-site bench scale studies were conducted at a mill located in Manitoba, and a treatment strategy identified. Modifications suggested from the study were made that included altering the waste streams to the clarifier. Following the mill changes, further on-site bench scale studies were conducted in 1985 that included the refining of the treatment strategy and process optimization. A report on this work is to be completed by 31 March, 1986.
(2) For 1986/87 it is proposed that a full scale demonstration of the treatment strategy developed at bench scale be conducted. Final optimization of the treatment variables will be undertaken during a four month full scale demonstration period. Completion 31 March, 1987.

STATUS REPORT - APRIL 1986 TO MARCH 1987

The pulp and paper mill at Pine Falls considered implementing inhouse changes to reduce solids losses to the environment based on the results of the WTC bench scale treatability studies. To date, no information has been received as to whether these changes have been completed.

As a consequence of their planned in-house modifications and a policy of "a chemical free treatment system", the mill has decided not to proceed with any further activities that would involve the use of chemical aids in assisting clarification in the woodroom facilities. Without the mill's support, no further WTC activity could be undertaken in demonstrating the effectiveness of the enhanced solids removal strategy. The mill

acknowledged and were appreciative of all the assistance provided by the WTC, but felt that their own improvements made to date were satisfactory. According to their data, their current total mill suspended solids discharges have generally been just under the mill discharge requirements.

To effectively complete this project, and demonstrate enhanced solids removal using coagulants, another pulp and paper mill had to be identified which was willing to make the total committment for the full scale demonstration of the treatment strategy. This was not accomplished this fiscal year.

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: A. Zaidi

PROJECT NO: 99981 TEL: 336-4618

ACTIVITY NO: 2400

TITLE: GOLD MINING EFFLUENT TREATMENT

OBJECTIVE:

1) To continue to collect and disseminate information on alternative technologies to treat gold mining effluents as well as undertake appropriate R&D to ensure that technically and cost effective technologies are demonstrated for the treatment of gold mining effluents.
2) To provide technical advice and assistance to personnel from the C&P-Regions and Industrial Programs Branch, industry and provincial and other government agencies, as required.

RELEVANCE:

The project is a continuation of the work from previous years and is designed to fill the knowledge/data gap in the application of alternative technologies to reduce the discharge of deleterious and toxic substances from gold mining and milling operations in Canada.

WORK PLAN:

1) By Sept. 30, 1986, publish the results of the assessment of the SO_2/Air process conducted in 1985/86.
2) By Sept. 30, 1986, publish the results of the work completed in 1985/86 on the dynamic model for natural degradation of cyanide.
3) By Mar. 31, 1987, complete the work on the development and testing of a high intensity UV reactor for destroying iron cyanide in industrial effluents (Unsolicited Proposal).
4) By Mar. 31, 1987, complete a preliminary evaluation of the effectiveness of activated carbon for detoxifying tailings pond overflows from gold milling operations.
5) Continue to provide technical support to HQ, Regional, Provincial and other agency and industry personnel, as required, on the application of technically feasible and cost-effective technologies for treating gold mine and mill effluents.
6) To assist in organizing a national, comprehensive technology transfer seminar, and participate in it as appropriate.

STATUS REPORT - APRIL 1986 TO MARCH 1987

General

The activities under this project included dissemination of information on the control of the alkaline chlorination process, continuation of the work on the development of a predictive model for natural degradation of cyanide in dynamic systems, evaluation of the performance of full scale effluent

treatment systems, development of a high-intensity UV reactor for destroying iron cyanide wastes, dissemination of information collected by the WTC and provision of advice to industry and other government agencies.

Alkaline Chlorination

Results from the pilot plant work on the residual chlorine based automatic control of the alkaline chlorination process were presented at the 41st Purdue Industrial Waste Conference held in May. The final report on this work has been circulated to relevant C&P and industry officials.

Natural Degradation

A mathematical model for a dynamic system (e.g. tailings ponds) was developed assuming well-mixed conditions in the pond. However, during the verification phase, a need to obtain more data from full scale operating systems was identified, particularly for flow-through tailings ponds.

Site visits were made to the Echo-Bay Lupin Gold Mine located 400 km north of Yellowknife, N.W.T. and Detour Lake, Dome and Kerr Addison Mines located in northeastern Ontario, to solicit their cooperation in providing additional data for the verification of the model for natural degradation of cyanide. Plans were developed for field studies at these sites and the studies commenced in September, 1986.

The data being collected from the sampling programs at the four gold mines (Echo-Bay Lupin, Detour, Dome and Kerr Addison) are stored on a microcomputer. The mathematical model, originally on a main frame computer, was transferred to a microcomputer and made more user friendly.

The first draft of the report entitled "Development of a Dynamic Model for the Prediction of Natural Degradation of Cyanide" was received, reviewed and returned to the contractor for the necessary revisions.

SO_2/Air Process

A draft report on the performance evaluation of the INCO process installed at McBean Mines was prepared and circulated to the relevant INCO and C&P officials. Comments resulting from the review of the draft have been incorporated into the final report which is currently being reviewed by INCO. A paper on the performance of this system was presented at the annual meeting of the Water Pollution Control Federation, October, 1986.

A study to evaluate the performance of the SO_2/Air process installed at Equity Silver Mine in B.C. was initiated. The study will continue into the next fiscal year. The data collected to date show that the process is working as expected and is able to reduce the total cyanide concentration in the mill discharge to the tailings impoundment area to less than 1 mg/L.

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High Intensity UV Reactor

Work was completed on the development of a prototype high intensity UV reactor under the contract (UP) awarded to Trojan Technologies. At year end, the contractor submitted a draft report which was reviewed by the WTC staff. A final report on the work is expected early next fiscal year. This work was supported by EMR and IPB, EC.

Technical Advice

Advice was provided to a metal finisher (National Standards of Guelph,Ontario) on the state-of-the-art of iron cyanide destruction technologies. The Department of Indian Affairs, regional offices of C&P and private consultants were advised on the practicality of available technological alternatives for treating gold mill effluents. Assistance was provided to C&P Headquarters on several aspects of problems related to gold mill effluent treatment. Several private consultants and gold industry officials (e.g. Stanley & Associates, Randolph International, Dome Mines, etc.) requested and were given advice and information on specific aspects of gold mill effluent treatment.

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: A. Zaidi

PROJECT NO: 99982 TEL: 336-4618

ACTIVITY NO: 2300

TITLE: TREATMENT OF AQUEOUS EFFLUENTS FROM IN-SITU BITUMEN/HEAVY OIL RECOVERY

OBJECTIVE:

To develop and demonstrate cost-effective technologies for the treatment of wastewaters from bitumen/heavy oil operations. Technologies will be such as to permit the recycling of wastewaters, or surface water discharge.

RELEVANCE:

Produced water associated with the recovery of heavy oil by in-situ techniques contains a number of undesirable constituents. These are (1) emulsified and free oil, (2) dissolved toxic organics, (3) dissolved metals (4) suspended inorganic and organic solids, and (5) dissolved inorganic salts. Treatment of the "produced" water is required such that it can be recycled for steam generation, or discharged to surface waters. Efforts to date have been made to treat this water using demulsification techniques followed by a complex series of treatment processes to remove other undesirable constituents. Significant deficiencies have been identified in the technologies employed to date. In 1986/87, the focus will be on field testing and demonstration of vapour compression evaporation for TDS removal, granular media filtration for oil and S.S. removal and activated carbon for the polishing of treated produced water.

WORK PLAN:

In FY 86/87, activities will be focused as follows:

(1) By Sept. 30, 1986, publish the comprehensive data (conventional and non conventional parameters) on produced water characteristics collected in 1985/86.

(2) By Sept. 30, 1986, complete pilot tests at Husky's site on oil and suspended solids removal by granular media filtration. Prepare a comprehensive report on the evaluation of the various process options for oil and S.S. removal.

(3) By Aug. 31, 1986, complete the bench scale work on dissolved organics removal from produced water and mobilize for field evaluation/demonstration.

(4) Subject to reaching agreement with AOSTRA and industry, by March 31, 1986, start activities for field tests at a site in the Lindberg area of Alberta for TDS and other contaminants removal from produced water using vapour compression. Complete this work by March 31, 1987.

(5) By Dec. 31, 1986, complete bench scale work on the use of membranes for the removal of TDS and other contaminants as well as work on any required pretreatment processes, e.g. silica removal.

PROJECT 99982
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STATUS REPORT - APRIL 1986 TO MARCH 1987

General

Negotiations with the Alberta Oil Sands Technology Research Authority (AOSTRA), five oil companies and the WTC, continued throughout the year. Specific aspects with respect to financial and personnel support and technical details of the field study on total dissolved solids removal (and other contaminants) from produced water in the Lindberg area of Alberta were agreed upon. At year end, finalization of the Letter of Agreement was underway.

Other government departments, specifically the Energy Resources Conservation Board (ERCB) in Alberta, Alberta Environment, Saskatchewan Energy, Mines and Resources, Saskatchewan Department of Environment and Energy, Mines and Resources-Canada, were kept informed of the status of the project.

Field Study at Lindberg, Alberta

Field work was started early in 1987. Construction, modification and testing of the filtration units (8 and 90 cm diameter units) were completed. Site preparation and installation of workshop and laboratory trailers, and tanks were completed by year end.

Bench scale filtration work commenced in March, 1987. Work conducted to date consisted of (i) screening of eight filter aids, including both inorganic and polymeric types (ii) jar testing of the three most promising types (ferric chloride, polyaluminium chloride and Dearborn 3715, a high molecular weight cationic polymer) and (iii) conducting filter runs using the 8 cm diameter filter and 1 and 5 mg/L polyaluminium chloride (as aluminium).

Discussions with major suppliers of evaporation equipment were held to determine the vapour compression evaporation unit best suited for the field work. Process configurations discussed were horizontal and vertical falling film modes, both capable of running in seeded slurry modes. Evaporator companies contacted were Aquachem Water Systems, Israel Desalination Engineering, Resources Conservation Co., and Envirochem. Of these companies, the horizontal falling film vapour compression evaporator (VCE) manufactured by Aquachem was selected. Discussions were subsequently held with Petwa Canada Inc., Calgary, which distributes the units in Canada, with respect to retrofitting a 40 L/m unit used for seawater desalination and modifying it to allow for computer data acquisition.

Corrosion aspects of the VCE unit with respect to the suitability of the materials of construction used in the unit to be supplied by Petwa for produced water treatment were addressed. A contract was awarded to a consultant specializing in corrosion monitoring to examine the materials of construction for the VCE unit before its placement in the field. Following

this examination, an experimental program will be developed to monitor the rate of corrosion of the tube bundles, as well as coupon tests to ascertain the extent of corrosion likely to occur in the evaporator sump and other sensitive areas, during the field tests.

Concentrate disposal options being considered are crystallization and deep well disposal. A proposal for the off-site crystallization work by Aquachem was received. Discussions were initiated with the Alberta Research Council regarding the possibility of using a computer simulation model for scale prediction in oilfield formations to assess the potential for formation plugging when the concentrate is disposed of in deep wells.

Ongoing Work at the WTC

Sampling and analyses of produced water from over 20 EOR operations were completed this year. Also included were samples of the skim tank, pilot IGF and pilot filter at Husky Aberfeldy (Lloydminster) collected during the field study conducted during this past summer. Supplemental studies were also undertaken to address problems with respect to changes in concentrations of specific parameters including phenolics, suspended solids, pH, and alkalinity due to sample aging. A draft report of the results of the characterization program will be completed by mid 1987.

Site visits were made to BP Wolf Lake, ESSO Cold Lake, and SUNCOR Fort Kent in early September, 1986. Plans were formulated to conduct a process evaluation of full scale oil removal processes, including skim tank, IGF and various filter types (sand, "Hydromation", coalescers). The program will provide data to supplement the existing data base on produced water quality and also will be used to compare the data collected from the field pilot filter study. These sampling campaigns will address as needed, the effect of sample aging on specific parameters including TSM, TOC, and phenolics.

Experimental work investigating a simplified spectrophotometric method for the analysis of oil and grease in produced water was also completed. The method, involving absorption of light in the visible range, was also compared experimentally with the standard APHA-AWWA JWPCF method and found to be as reliable. An evaluation of alternative solvents for the extraction of O&G from produced water samples was also carried out. It was found that dichloromethane (DCM) provided the highest quantitative recoveries.

Oil and Suspended Solids Removal

The filtration work on oil and suspended solids removal was completed by Dearborn Consultants this past year with field trials at Husky Oil - Aberfeldy heavy oil recovery opertion near Lloydminster, Alberta. The pilot filter skid was shipped to the site in early May. During May and June the filter was commissioned and preliminary coagulant screening tests

were conducted. Preliminary runs were performed from 1 July to 15 August to establish optimum operating conditions for the pilot filter. Following the shakedown and optimization period, the pilot filter was run in a "demonstration mode" from 18 August to 16 September. The pilot facilities were decommissioned during the week of September 22. The final report of the pilot filter study was received at year end.

Instrumentation

Several oil monitoring and process control devices were assessed by Dearborn Consultants for their suitability to produced water treatment. The units tested in-house were the Teledyne Analytical Instrument, CE Invalco monitor and an AGAR probe, along with two streaming current detectors (SCD's) manufactured by Milton Roy and Kerrigan-Dupree. The in-house tests indicated all three oil-in-water detectors to be promising and these were subsequently tested in the field at the Husky-Aberfeldy site during the field filter tests. In-house tests with the SCD's proved unsuccessful.

The field tests indicated significant problems in the operation and maintenance of all three oil monitors. None of the units performed as anticipated and recommendations were made to the suppliers for modifying the units to make them more reliable. A report on this study was submitted at year end. This activity was funded in part under the DSS-UP program and by the Department of Energy, Mines and Resources.

During February to March, 1987, Dearborn Consultants were retained to conduct a rigorous bench scale test protocol to a modified Agar probe, to evaluate its usefulness as a monitor at oil-in-water concentrations in the range of 1 to 10%. If effective, the monitor could be used to provide "protection" to produced water treatment processes by monitoring and warning of high oil concentration excursions. The tests indicated limited applicability in the treatment of produced water. A final report of this work is currently being drafted.

Dissolved Organics Removal

Oxidation - A draft report summarizing the results of the oxidation experiments carried out in 1985 on dissolved organics in produced water is under review.

Carbon Adsorption - No significant activity.

TDS Removal

Specifications for a pilot reverse osmosis unit were developed, and a contract awarded to a local supplier for its construction. Contacts with

several membrane suppliers were made to discuss the potential of their membranes for application to produced water treatment.

Specifications for an electrodialysis unit were developed and a contract was awarded to Membrane Technology Systems of California. The unit was delivered in March, 1987.

Pretreatment studies, using cross flow microfiltration for the removal of oil and suspended solids prior to reverse osmosis and electrodialysis processes were initiated. Experiments using produced water from the Murphy-Lindberg site (skim tank effluent) were conducted. The microfiltration unit has a capacity of 20 L/m and is supplied on loan to the WTC by Norton Products, Massachussets. Experimental parameters investigated to date include the effect of pH, temperature, module pore size rating, operating pressure and flow velocity. A suitable cleaning procedure was also devised. Significant improvements in filtrate flux were obtained with a decrease in pH to 5.5 compared with operation at neutral pH conditions, as well as with a lower pore size rating (0.45 μm compared to 1 μm) and elevated temperature (up to 43°C).

The results of the bench scale evaporation tests on produced water from four heavy oil locations were published and presented at the 37th Annual Canadian Institute of Mining - Petroleum Section in Calgary in June.

Silica Removal

Preliminary bench scale tests on the removal of silica from synthetic mixtures of produced water were conducted at the WTC. The objective of this work was to assess the effect of dissolved organics found in produced water on the adsorption of silica on activated alumina as well as their effects on the regeneration of the activated alumina. The tests were performed using two synthetic mixtures, one consisting of relatively hydrophilic organics and the other relatively hydrophobic organics found in the produced water. The results showed that the presence of organics did not reduce the adsorption of silica on activated alumina, and a portion of the silica removed by activated alumina is adsorbed irreversibly and can not be eluted during regeneration by an alkali/acid wash. A draft report on this work is under review.

Acknowledgements

Much of this work was supported by the Panel on Energy Research and Development (PERD).

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: L. Simovic

PROJECT NO: 99986 TEL: 336-4696

ACTIVITY NO: 2400

TITLE: TREATMENT OF LEACHATE FROM LANDFILLS

OBJECTIVE:

To assess the existing treatment technologies and develop and demonstrate technically feasible, cost effective technologies for the treatment of leachate or contaminated groundwater from landfills.
To develop a design strategy for each process used for the treatment of leachate.
To provide technical support to C&P-IPB and Regional Offices, other federal and provincial agencies, industry and other practitioners in resolving problems with leachates from active and abandoned landfills.

RELEVANCE

Leachates from active and abandoned hazardous waste landfills are considered to be a high priority environmental problem. Remedial technology/ies tried to date have to be critically assessed and new and innovative technoligy/ies must be developed and demonstrated to resolve this problem.

WORK PLAN:

Specific activities to be undertaken in FY 1986/87 will include:
1) Completion of a comprehensive R&D strategy for the treatment of leachates.
2) Development of design strategies for treatment technologies effective in leachate remediation (computer based).
3) Conduct or assist in the conduct of bench or pilot scale studies on the treatment of various problem leachates e.g. Gloucester site (Ont), Ladner (B.C.), Hyde Park (Niagara R.), Elmira (Ont), Breslau (Ont), and an industrial site in Toronto.
4) Design and construct appropriate mobile pilot scale facilities for the treatment of leachates.
5) Provide technical support to C&P-Regional and IPB personnel, OGD's and industry as required with consideration of sites in the Niagara River area, Sarnia area (Ont), Amherst, N.S., CFB-Gagetown, N.B., and leachate from hog fuel (P&YR).

STATUS REPORT - APRIL 1986 TO MARCH 1987

The focus of this project is on the development and demonstration of technically feasible, physical/chemical technologies to treat contaminated groundwater or leachates from landfill sites. During the past three years, the specific site of concern has been the Gloucester municipal landfill located near Ottawa, Ontario.

One of the initial experiments performed on the contaminated groundwater from the Gloucester site was a bench scale study carried out at the WTC to examine the efficiency of removal of the organics by various chemical oxidants. A paper on the results of this study was submitted for publication to the Water Pollution Research Journal of Canada. A poster on the work was exhibited at the Technology Transfer Conference in Toronto in December, 1986.

During the summer of 1986, an experimental design was developed, and a seven week pilot-scale field study was carried out at the Gloucester site (with partial funding by Transport Canada). The field study involved air stripping experiments, for the removal of volatile organics from the contaminated groundwater, and the treatment of the off-gases from the stripper by activated carbon adsorption. The packed air stripping column and two granular activated carbon columns were designed and built in-house. This work was carried out in association with Zenon Environmental Inc. (UP), and the River Road Environmental Technology Centre, who conducted studies involving the use of reverse osmosis and liquid-phase activated carbon adsorption.

All the samples collected during the WTC study were analyzed by the Laboratory Services Section. The analysis of the data has been completed. The results show that the proposed groundwater quality objectives and the MOE's ambient air quality standards can be reached at this site using air stripping and vapour-phase activated carbon adsorption, respectively.

A paper describing this work was accepted for presentation at the Second International Conference on New Frontiers for Hazardous Waste Management, Pittsburgh, Pennsylvania, September, 1987. A poster, summarizing the results, was prepared.

A comprehensive report presenting the results of this study and a preliminary design of the full-scale treatment plant for this site was drafted. In the final analysis, the choice of process will be dictated by economic considerations and the effluent quality objectives that must be met.

An air stripping column, 61 cm (2 ft) diameter and 5.2 m (17 ft) high was purchased from Croll-Reynolds. The column is divided in three sections with two sampling ports on each section. It is made of fiberglass reinforced plastic and designed to handle water flow rates of 57 to 227 L/min (15-60 US gpm). A belt driven air blower (1 HP) was provided for a typical air flow of 17 m^3/min.

Several meetings were held during 1986 with personnel from consulting organizations, universities and provincial government agencies to discuss comprehensive proposals related to the decontamination of aquifers. Two major proposals resulted related to cleanup of the site of an organic chemical

manufacturer, and the other the decontamination of an aquifer contaminated by a hazardous waste dump.

Technical advice and assistance in this project area was provided to a number of municipalities, industries and other companies.

Jim Schmidt attended the first Working Group Meeting of the NATO/CCMS Pilot Study on Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater. It was held on 16-20 March, 1987, in Karlsruhe, Federal Republic of Germany. Two background documents were prepared for the meeting. The next meeting is scheduled for November 11-13, 1987, in Washington, D.C., U.S.A.

SECTION: PHYSICAL/CHEMICAL PROCESSES PROJECT MGR: J.W. Schmidt

PROJECT NO: 99988 TEL: 336-4541

ACTIVITY NO: 2200

TITLE: TECHNICAL SUPPORT: C&P - HQ AND REGIONS

OBJECTIVE:

To provide technical advice and assistance to C&P-HQ and Regional personnel involved with resolving pollution problems in the following areas of concern:
(1) assessment of membrane technology applications in the food and other industrial sectors.
(2) metal finishing effluent technologies,
(3) treatment of effluents from coal mining/coal preparation plant operations,
(4) cleanup of the Sydney, N.S. tar ponds,
(5) acidic drainage from mining operations and "acid slates",
(6) Upper Great Lakes Connecting channel activities,
(7) International Joint Commission "areas of concern",
(8) wood protection and wood preservation plant effluents,
(9) Fraser River Estuary projects,
(10) C&P - OR/MOE initiatives concerning source control of industrial effluents generally,
(11) C&P - QR initiatives
(12) WMD - IPB initiatives concerning hazardous waste management.

RELEVANCE:

Effective management of industrial wastewaters, particularly those containing toxic chemicals, is of concern to the Department.

WORK PLAN:

Provide technical advice, assistance and support as required to support C&P activities.

STATUS REPORT - APRIL 1986 TO MARCH 1987

In response to a request from C&P-AR Halifax, D. Vachon conducted treatability tests to address a suspended solids removal problem from Rio Algom's Tin mine at East Kemptville, NS. Polyelectrolytes from three chemical suppliers were evaluated at bench scale at the WTC laboratories in treating tailings slimes from the mill. Suspended solids reductions from >20 000 mg/L to ~20 mg/L were achieved based on the suppliers suggested dosages. Recommendations as to the effectiveness and treatment strategy were forwarded to C&P-AR Halifax personnel.

In response to a request from C&P-AR Halifax, D. Vachon assessed the treatability of a PEI meat processing plant effluent by physical chemical means. The results of this assessment were included in a package prepared by the Biological Processes Section.

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In response to requests from DIAND (Yellowknife region) personnel, D. Vachon held discussions about total residual chlorine (TRC) analytical techniques, particularly as they could apply to the analyses of TRC from the Giant Yellowknife gold mining operations.

D. Vachon attended a series of meetings (January to March) to review initial drafts of the training materials on pollution control in the metal finishing industry for owners/managers/operators of metal plating & finishing operations.

A paper was prepared at the request of C&P-IPB and presented at the Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March, 1987.

The following papers/proposals were reviewed by staff:

Fell, W.F., and M.T. Reid, "Effluent Treatment Associated with a Modernization Program at Ontario Paper Company." being considered for publication in Pulp & Paper Canada. (April 1986)

McCandless, R., "Settleable versus Suspended Solids" circulated for comments from DIAND, DFO, DOE personnel. (April 1986)

A proposal submitted to TSB - IID by COMINCO METALS for consideration under the DRECT program. (May 1986)

Little, H. "Chemical Contamination of Hamilton Harbour: A Review", Canadian Technical Report of Fisheries And Aquatic Sciences. (Draft Edition) (October 1986)

Murphy, P.A., "Studies on the Chemical Reduction of the Selenate Ion in Water", a paper submitted to I&EC FUNDAMENTALS for consideration for publication. (February 1987)

A proposal to TSB - IID from IREQ for consideration under the DRECT program. (March 1987)

A number of proposals from a variety of organizations were reviewed under the DSS Unsolicited Proposal program.

FISCAL YEAR 1986/1987 - WTC SUPPORT SERVICES ACTIVITIES

The following represents a brief status report and description of important developments made by the Laboratory Services Section. A similar presentation is included for the Computer Services Section with emphasis placed on a description of the hardware and software and its application to WTC projects.

During Fiscal Year 1986/1987 the Engineering Support Services Section was responsible for equipment specification, construction and maintenance of laboratory and pilot scale processes and the supporting instrumentation and control systems required for development and demonstration of processes being investigated by the process sections. It is acknowledged that the Engineering Support Services Section's contribution to the WTC projects represents an essential component of the WTC's output and thus, their contribution is identified throughout the process development section's reports.

LABORATORY SERVICES SECTION

The section provides virtually all the analytical sevice, including QA/QC, required by the programs of both the Wastewater Technology Centre and C&P Ontario Region. In addition, both QA/QC and GC/MS support is given as required to other Regions and Headquarters. A further important function is the consulting and advisory role of laboratory staff in both planning and organizing phases of many projects.

There are three separate groups within the section, viz. inorganic, organic and radiochemistry. The laboratories are well equipped with such instrumentation as automated wet chemistry analyses, atomic absorption and plasma spectrophotometers, gas chromatographs, mass spectrometers, liquid chromatographs, scintillation counter and spectroscopy units. Most of these systems are coupled with computerized data handling equipment. The parameters or groups of compounds most commonly requested for analysis continue to be nutrients, phenols, metals, cyanide, volatile acids, base neutral and acid extractables, PAHs and PCBs.

Examples of the section's workload other than routine analyses are as follows:

Upper Great Lakes Connecting Channel Study

This was the single largest project of the year and resulted from the participation of C&P Ontario Region in a point source survey as their contribution to the study. Laboratory staff played a major role in all aspects of the planning of the program including timing, sampling, preservation and determination of QA/QC requirements. Approximately 400

samples from industrial and municipal treatment plants were analyzed for a variety of conventionals, metals, base neutral and acid extractables and organochlorine compounds. All samples also required identification of unknowns by GC/MS. Because of the emphasis placed on validated data within the entire project, protocols were introduced requiring the use of surrogates in every sample analyzed by GC/MS.

All volatiles and some semi-volatiles analysis for this program was performed by commercial laboratories and this also required extensive QA/QC carried out by WTC laboratories including preparation of standards or spiking of samples.

Monitoring the Fate of Toxic Organic Chemicals

A radiotracer technique was refined and expanded to monitor the fate of toxic organics applied to land. The determination of specific toxic components particularly in an oily matrix by GC, HPLC or MS is difficult due to large amounts of interfering compounds present. The use of ^{14}C labelled chemicals allows accurate quantitation of the compound of interest since the background matrix does not interfere. The technique is useful in laboratory studies designed to investigate factors affecting biodegradation. Large amounts of accurate data can be generated quickly to support modelling studies. Degradation of the compound can be demonstrated by identification of a metabolite.

In a typical study, soil, oily waste or other treatments and a ^{14}C labelled compound are placed in a biometer flask (a modified Erlenmeyer flask). A sidearm in the flask contains NaOH which absorbs CO_2 and other gaseous compounds. The NaOH can be extracted with toluene, and both phases counted using a liquid scintillation counter to distinguish organic and inorganic ^{14}C. Total and $^{14}CO_2$ can be determined by ion chromatography using refractive index and scintillation detection. The soil sample can be extracted with solvent and ^{14}C in the extract separated into parent compound and metabolite by reverse phase gradient HPLC with a scintillation detector. The extracted soil can be pyrolyzed and the off-gases trapped and counted to determine ^{14}C fixed to the soil or incorporated into biomass.

This year labelled compound degradation studies have been carried out on naphthalene, anthracene and 3,4,5,3',4',5' hexachlorobiphenyl. A typical study uses 15-48 individual biometer flasks with the NaOH being sampled and analyzed once or twice per week. Mass balances of total ^{14}C typically vary from 90-110% recovery.

New Equipment

A Tekmar LCS2 Purge and Trap apparatus with ALS autosampler was coupled to a Carlo-Erba GC with ECD and FID and set up to analyze US EPA and MISA volatile organic compounds. Considerable difficulty with contamination was experienced and resolved.

A Waters gradient HPLC system with a Berthold Flow Through Radioactivity Monitor, and a Waters Ion Chromatography system using a Refractive Index detector and the Radioactivity monitor was set up in support of land disposal programs. Data acquisition and instrument control is done with an IBM-XT running Waters WIRC software.

Committee Involvement

WTC laboratory staff have been extensively involved in the development of sampling and analytical protocols for the MISA program. Committee membership has included the MISA Analytical Methods working group, Sampling Subcommittee and OFIA Analytical Working Group. Upper Great Lakes Connecting Channel Study involvement included the Point Source Working Group, Non-Point Source Working Group and Data Quality Working Group. Laboratory staff also participated in the Dynamic Strategies Steering Committee.

COMPUTER SERVICES SECTION

The WTC has been involved in automated process control in wastewater treatment applications since 1978. Expertise has been developed in-house utilizing the real-time, multitasking capabilities of the Hewlett Packard HP 1000 minicomputer to accomplish direct digital control and distributed process control techniques in full scale and pilot scale wastewater treatment processes.

The main computer facility consists of twin HP 1000 E series minicomputers, one used for real-time data acquisition and control and the other primarily for program development, data analysis and hardcopy graphics output. The real-time computer has two smart front-end microprocessors that allow direct digital control to be implemented on any of eight instrumented wastewater processes. Typical parameters monitored included dissolved oxygen, biological solids, pH, air flow, pressure, temperature, liquid flow, gas flow, chlorine and TOC. This system executes 24 hours per day, seven days a week and has the capability of sounding alarms due to computer failure, instrumentation malfunction, process upset or data communications failure.

Five microcomputers with dedicated input/output racks also collect data and control treatment processes while located directly on the pilot plant floor or in a trailer. Data from these microcomputers are eventually transmitted to the HP 1000 via a RS232C asyncronous serial link.

A series of programs written in FORTRAN on the HP 1000 generate plots (fn an unattended mode of operation). In this way, 24 hours of graphical data is available to the project engineer each morning.

In the past year usage of our interactive graphics package has reached a point where approximately 800 plots per month are generated. The acquisition of additional computer memory and an HP 7550 auto paper feed plotter has greatly increased hardcopy throughput.

An interactive statistics package is available on the HP 1000. This package also has an interface to our technical graphics software. The use of STAT80 has resulted in an overall increase in statistical capability for the WTC and at the same time reduced the need for custom statistics programming.

Additional microcomputers were purchased to meet the needs of WTC staff in processing and analysing a vast quantity of research data. In total the WTC presently have over 50 microcomputers in use. The typical microsystem includes 640 Kb memory, dual floppy disks, 300/1200 baud internal modem, graphics, asyncronous interface and printer or HP 7475 plotter. The microcomputer systems are used heavily for spreadsheet and word processing applications. Communications packages are available that allow access to any computer system supporting asyncronous communications, typically the HP 1000 at the WTC, the mainframe CYBER at the CCIW, or the VAX system at McMaster University.

Several copies of REFLECTION 3, an IBM compatible HP graphics emulation software package, were purchased. Micro users now access the HP 1000 based graphics system directly. Uploading and downloading of data is also supported by REFLECTION.

Data communication from field sites as far away as Lloydminster, Alberta and Portage-la-Prairie, Manitoba have been successfully carried out using Telecom Canada's ENVOY100. Communications links between research groups and universities around the world have been established using the NETNORTH communications network. This network was used extensively between WTC staff and members of the LUND Institute in Sweden.

Just prior to year end, a used HP 1000 model A-900 minicomputer was purchased for a fraction of its original cost. The A-900 is the top-of-the-line HP 1000 and, it is felt, will increase the throughput of the current 1978 vintage E series by a factor of at least 10. Considerable effort will be required before this system will be available for us as a replacement for the non real-time mini.

Over the past year, work on pilot plant #7 has resulted in a reliable micro based real-time system that incorporates the control micro-system SAFE 8000 front-end.

Still an important task for the Computer Services Section this year has been the modification of data acquisition and process control software on a Hewlett Packard A-600 minicomputer located in the WTC trailer at the Ontario Ministry of Environment's wastewater treatment facility in Tillsonburg, Ontario. Data collected from this process is transmitted via phone link automatically to an HP 1000 computer at the WTC in Burlington where it is plotted, analysed and eventually archived to magnetic tape.

APPENDIX A

WASTEWATER TECHNOLOGY CENTRE STAFF LIST

March 1987

WASTEWATER TECHNOLOGY CENTRE

STAFF LIST

ADMINISTRATION

A/Director	Dr. B.E. Jank	336-4599/4740
Secretary:	Ms. J.E. DeLorey	336-4740
Administrative Officer:	Mr. J.R. Dobson	336-4667
Accounts:	Mrs. J.A. Tonaj	336-4666
	Mrs. M. Gaskin (T)	336-4666
Central Registry:	Mrs. J. Stafford	336-4590
Stores	Mr. L. Rowe (T)	336-4561
Computer Services	Mr. B.A. Monaghan	336-4548

PHYSICAL/CHEMICAL PROCESSES SECTION

Head:	Mr. J.W. Schmidt	336-4541
Secretary:	Mrs. G.A. Graham	336-4665
Scientific and Professional:	Mr. D. Vachon	336-4558
	Mr. D.W. Averill	336-4747
	Mrs. L. Simovic	336-4696
	Mr. A. Zaidi	336-4618
	Ms. S. Kok (T)	336-4750
	Mr. G. Leopold (T)	(403)724-4044
Technical Support:	Mr. L. Whittle	336-4514
	Mr. J.A. Wood	336-4613

BIOLOGICAL PROCESSES SECTION

Head:	Dr. H. Melcer	336-4546
Secretary:	Mrs. C. Davey-Zarifis(T)	336-4690
Scientific and Professional:	Dr. D. Chapman	336-4621
	Dr. E. Hall	336-4715
	Mr. R. Jones	336-4686
	Mr. G. Speirs	336-4745
	Mr. J. Bell (T)	336-4564
Technical Support:	Mr. W.K. Bedford	336-4564
	Mr. J. Matthews	336-4589

RESIDUE MANAGEMENT SECTION

Head:	Mr. H.W. Campbell (A) (formerly T.R.Bridle)	336-4717
Secretary:	Mrs. S.V. Perrone	336-4721
Scientific and Professional:	Dr. M.D. Webber	336-4519
	Mr. H.C. Campbell	336-4717
	Dr. T.W. Constable	336-4716
	Mr. P. Côté	336-4605
	Mrs. T. Bulman	336-4720
	Mr. M. Latham (T)	336-4502
	Mr. A. VanKester (T)	336-4502
Technical Support:	Mr. P.J. Crescuolo	336-4539

LABORATORY SERVICES SECTION

Head:	Mr. P.J.A. Fowlie	336-4633
Scientific and Professional	Ms. L. Taylor	336-4535
	Mr. B. MacGillivray (T)	336-4535
Technical Support:	Mr. J.L. Fraser	336-4615/4719
	Mr. G.J. Lawrence	336-4615
	Mr. J.M. Dupuis	336-4615
	Mr. J. Rajkumar	336-4615
	Mr. D. Ide	336-4633
	Ms. J. Ritch	336-4535
	Mrs. S. Hay-Pole	336-4774
	Mrs. S. Abbott	336-4204

ENGINEERING SUPPORT SERVICES SECTION

Head:	Mr. R.G. Gillespie	336-4574
Technical Support:	Mr. S.C. Lee	336-4574
	Mr. E.G. Luxon	336-4574

T - Term Positions

APPENDIX B

1986 WTC PAPERS, REPORTS AND PRESENTATIONS

PUBLICATIONS: REPORTS AND PAPERS - 1986

Bedford, W.K. and H. Melcer, "The Fate of Trichloroethylene in Activated Sludge Systems", presented at the 21st Canadian Water Pollution Research Conference, Burlington, Ontario, April 30, 1986.

Bridle, T.R. and H.W. Campbell, "Oil from Sludge: A Technology Update", presented at the 9ie AQTE Symposium sur le traitement des eaux usées, Montreal, Quebec, November 11-12, 1986.

Bulman, T.L., P.J.A. Fowlie, S. Lesage and M.D.Webber, "Canadian Research on the Use of Soil for Treatment of Petroleum Wastes", Proceedings of the 13th Congress of the International Society of Soil Science, Hamburg, Germany, August 13-20, 1986.

Camilleri, S.M., T.L. Bulman and J. Cairns, "The Effect of Soil Amendments on the Fate of ^{14}C-3,4,5,3',4',5'-hexachlorobiphenyl in Soil", presented at the Annual Meeting of the Soil Science Society of America, New Orleans, Louisiana, November 30-December 5, 1986.

Campbell, H.W., S.L. Siverns, P.J. Crescuolo and E.J. Harrison, "An Instrument for Automated Control of Sludge Conditioning", presented at the 9ie AQTE Symposium sur le traitement des eaux usées, Montreal, Quebec, November 11-12, 1986.

Chapman, D.T., "Tracer Studies at an Anaerobic Sludge Digester to Assess Alternative Mixer Configurations", presented at the 59th Annual Water Pollution Control Federation Conference, Los Angeles, California, October 5-9, 1986.

Constable T.W. and P.L. Côté, "Development and Applications of a Multiple-Batch Leaching Procedure", Environment Canada Report EPS 3/AT/1, April 1986.

Constable, T.W. and G. Ross, "Contaminant Solubilization in Bench-scale Recirculating Ash Transport Systems", Environment Canada Report EPS 3/PG/5, May 1986.

Constable, T.W. and G. Ross, "Trace Element Leaching in Bench-scale Recirculating Ash Transport Systems", Canadian Journal of Civil Engineering, 13, 1986.

Constable, T.W., L.J. Taylor, R.J. Rush, "The Effect of Three Sludge Processing Operations on the Fate and Leachability of Trace Organics in Municipal Sludges", Environmental Technology Letters, 7, 1986.

Constable, T.W. and R. Kissel, "Evaluation of Atmospheric Fluidized Bed Combustion (AFBC) Solid Waste Properties - 1983/84", Environment Canada Report EPS 3/PG/7, September 1986.

Constable, T.W. and S.E. Sawell, "Evaluation of Atmospheric Fludized Bed Combustion (AFBC) Solid Waste Properties - 1984/85", Environment Canada Report EPS 3/PG38, September 1986.

Constable, T.W. and W.J. Snodgrass, "Acidification and Radionuclide Leaching in Unsaturated Uranium Mill Tailings", Proceedings of the Second International Conference on Radioactive Waste Management, Winnipeg, Manitoba, September 1986.

Cornacchio, L.-A., E.R. Hall and J.T. Trevors, "Anaerobic Biodegradation Estimates for Industrial Wastewaters", presented at the 21st Canadian Symposium on Water Pollution Research, Burlington, Ontario April 30, 1986.

Fowlie, P.J.A. and T.L. Bulman, "Extraction of Anthracene and Benzo(a)pyrene from Soil", Analytical Chemistry, 54:721, 1986.

Frost, R.C. and H.W. Campbell, "Alternative Uses of Sewage Sludge", presented at the International Recycling Congress, Berlin, West Germany, October 29-31, 1986.

Goodin, J.D. and E.R. Hall, "Measurement of Anaerobic Reactor Sludge Activity", Proceedings Technical Transfer Workshop on Laboratory Scale Anaerobic Treatability Testing Techniques, Environment Canada, Wastewater Technology Centre, Burlington, Ontario, November 6, 1986.

Goodin, J.D., E.R. Hall and M.S. Manocha, "Phosphatase Activity and ATP Content as Indicators of Anaerobic Treatment Process Stability", presented at the 21st Canadian Symposium on Water Pollution Research, Burlington, Ontario, April 30, 1986.

Hall, E.R., "Biofilm Reactors in Anaerobic Wastewater Treatment", Biotechnology Advances, (in press), 1986.

Hall, E.R., "Anaerobic Treatment: Getting to Full Scale Successfully", Proceedings Technical Transfer Workshop on Laboratory Scale Anaerobic Treatability Testing Techniques, Environment Canada, Wastewater Technology Centre, Burlingotn, Ontario, November 6, 1986.

Hall, E.R. and G.P. Adams, "Anaerobic Treatment of Cheese Whey", Proceedings Seminar on Anaerobic Fixed Film Digestion, p.65, Ontario Ministry of Environment/Pollution Control Association of Ontario, Toronto, Ontario, November 5, 1986.

Hall, E.R., H. Melcer, L.-A. Cornacchio and R.M. Jones, "Anaerobic Treatment of Pulp and Paper Wastewaters", presented at the 2nd National Conference on Anaerobic Digestion of Industrial Wastes, Argonne National Laboratory, Chicago, Illinois, September 10-12, 1986.

Hall, E.R., C.F. Prong, P.D. Robson and A.J. Chmelauskas, "Evaluation of Anaerobic Treatment for NSSC Wastewater", presented at the TAPPI Environmental Conference, New Orleans, LA, April 21-24, 1986.

Hall, E.R., P.D. Robson, C.F. Prong and A.J. Chmelauskas, "Anaerobic Pilot Studies of NSSC Wastewater Treatment", TAPPI Journal, 69(12):79-84, 1986.

Hill, R.D. and G.W. Speirs, "Field Verification of On-Line Instrumentation at a Municipal Wastewater Treatment Plant", presented at the 13th International Association Water Pollution Research Control Conference, Rio de Janeiro, Brazil, August 1986.

Hosler, K.R. and T.L. Bulman, "Microcosm for Assessing the Fate of Organic Chemicals in Soil", presented at the 21st Canadian Symposium on Water Pollution Research, Burlington, Ontario, April 30, 1986.

Jones, R.M. and E.R. Hall, "Dynamic Modelling for Process Control of a High Rate Anaerobic Reactor", a poster presentation at the EWPCA Conference on Anaerobic Wastewater Treatment, Amsterdam, The Netherlands, September 15-19, 1986.

Jovanovic, M., K.L. Murphy and E.R. Hall, "Parallel Evaluation of High Rate Anerobic Treatment Processes: Retention Time and Concentration Effects", presented at the EWPCA Conference on Anaerobic Wastewater Treatment, Amsterdam, The Netherlands, September 15-19, 1986.

Kok, S., A. Zaidi and R. Solomon, "Total Dissolved Solids Removal from Water Produced During the In-Situ Recovery of Heavy Oil and Bitumen", presented at the 37th Technical Meeting of the Petroleum Society of CIM, Calgary, Alberta, June 8-11, 1986.

MacDougall, D.W. Averill and J.A. Wood, "Computer Monitoring and Control of Granular Media Filters", presented at the 59 Water Pollution Control Federal Conference, Los Angeles, California, October 5-9, 1986. (No publication available)

Melcer, H., "Control of Toxic Trace Contaminants in Municipal Wastewater Treatment Plants", presented at the Ontario Ministry of Environment Technology Transfer Conference, Toronto, Ontario, December 8-9, 1986.

Melcer, H. and W.K. Bedford, "Removal of Pentachlorophenol in Municipal Activated Sludge Systems", presented at 59th Water Pollution Control Federation Conference, Los Angeles, California, October 5-9, 1986.

Melcer, H. and W.K. Bedford, "The Fate of 4,6-Dinitro-o-cresol in Municipal Activated Sludge Systems", presented at the International Conference on Innovative Biological Treatment of Wastewaters, Washington, D.C., June 24-26, 1986.

Olsson, G., J. Stephenson and D. Chapman, "Computer Detection of the Impact of Hydraulic Shocks on Plant Performance", Journal Water Pollution Control Federation, 58:10, 1986.

Oleszkiewicz, J.A., E.R. Hall and J.Z. Oziemblo, "Performance of Laboratory Anaerobic Hybrid Reactors with Varying Depths of Media", Environmental Technology Letters, 7:445-452, 1986.

Simovic, L. and J.P. Jones, "Oxidation of Organic Micropollutants from Contaminated Groundwater", Water Pollution Research Journal of Canada, 22(1):187-196, 1986.

Speirs, G. W., "Direct Digital Control of the Tillsonburg, Ontario Municipal Activated Sludge Wastewater Treatment Plant - A Case Study", presented at the Computer Control of Wastewater Treatment Plants Workshop (AQTE/CSCE sponsored), Montreal, Quebec, May 8-9, 1986.

Stegemann, J., N. Cathcart, D. Friedman and A. Lieu, "Update on a Cooperative Investigation of Test Methods for Solidified Waste Characterization", presented at the 2nd EPA Symposium on Solid Waste Testing and Quality Assurance, Washington, D.C., July 16, 1986.

Webber, M.D., "Executive Summary - Manual for Land Application of Treated Municipal Wastewater and Sludge", Environmental Protection Publications, Conservation and Protection, Environment Canada, Ottawa, K1A OE7, 1986.

Webber, M.D., "The Potential for Agricultural Use of Waste Iron Oxides", presented at the Canadian Steel and Environmental Association meeting on Re-Use, Recovery and Treatment of Steelmaking Oxides, Montreal, Quebec, September 15, 1986.

Webber, M.D., L.E. Duvoort-van Engers and J. Berglund, "Future Developments in Sludge Disposal Strategies", Factors Influencing Sludge Utilization Practices in Europe, Davis et al. Eds., Elsevier Applied Science Publishers, 103-144, 1986.

Wood, J.A., "Development of an Automated Particle Counting System for Filter Monitoring", presented at the 21st Canadian Symposium on Water Pollution Research, Burlington, Ontario, April 30, 1986 and accepted for publication in "Filtration and Separation".

Young, D.N., D.W. Averill and J.A. Wood, "Computer Monitoring and Control of Granular Media Filters", presented at the 59th Annual Conference, Water Pollution Control Federation, Los Angeles, California, October 5-9, 1986.

Young, D.N., E. Vale and E.R. Hall, "Pilot Scale Anaerobic Biomass Acclimation Studies with a Coal Liquefaction Wastewater", presented at the International Conference on Innovative Biological Treatment of Toxic Wastewaters, Arlington, Virginia, June 24-25, 1986.

Zaidi, A., B. Conard, E. Devuyst, J.W. Schmidt and L. Whittle, "Performance Data for a Full-Scale Effluent Treatment System Using the SO_2/Air Process for Cyanide Removal", Proceedings of the Industrial Wastes Symposia, the 59th Conference Water Pollution Control Federation, pp 284-297, Los Angeles, California, October 5-9, 1986.

Zaidi, A., M. Jovanovic and L. Whittle, "Residual Chlorine Based Automatic Process Control for the Alkaline Chlorination Process Treating Cyanide Waste", presented at the 41st Purdue Industrial Waste Conference, West Lafayette, Indiana, May 13-15, 1986.